CHAPTER I.

THE NATURE AND SELECTION OF CLAYS—THEIR SPECIAL SUITABILITY FOR CERTAIN PURPOSES—SAND, BREEZE, AND OTHER MATERIALS USED.

BRICKS and tiles may be made from a large number of different kinds of material but they must usually possess a certain amount of plasticity.

The plasticity of clay is a property which distinguishes it from nearly all other mineral substances, and may be defined as the property of a body which enables it to absorb water in such a manner that the properly moistened body yields to mechanical pressure, but, when the pressure has been removed, the shape of the body remains as though the pressure were still acting upon it.

The cause of plasticity is practically unknown, but it appears to be closely related to the ability of each clay particle to surround itself with a coating of water sufficiently large to produce plasticity, but insufficient to cause the body to lose its shape when the external pressure is removed.

Clay or brick earth is almost the only substance of a mineral nature which possesses this plasticity, and then only when it is what geologists term "secondary clay," that is to say, clay which has been carried a considerable distance from the place where it was originally formed.

No satisfactory definition of "clay" is possible owing to its peculiar nature, though the development of plasticity when wet is its main characteristic. The term "brick earth" is much more suitable for general use, as meaning those clays, or mixtures of clay with other materials, which can be employed in the manufacture of bricks and tiles.

Strictly speaking, the term "clay" should be reserved for a certain hydrated silicate of alumina, or at any rate for earths chiefly composed of this material, unless the word is prefixed by another as "boulder-clay," "sandy-clay," etc.

The term "clay substance" is usually employed to denote the essential material in all clays, but the composition of this varies so greatly when different clays are treated by different processes for removing the other ingredients that the term has acquired a variety of meanings according to the person employing it. Thus Seger (who originated the term) employed it to represent a theoretical material, the nearest practical approach to which was obtained by carefully washing china clay and then treating this purified product with sulphuric acid, soda, etc. In this way he obtained a series of analytical results which were fairly constant for most varieties of clay, though the pure "clay substance" could only be won from certain clays; its proportion in the others was deduced from the analysis of the partially purified material.

The use of the term "clay substance" for the finest particles obtained by washing a commercial clay is unsatisfactory and should not be used. Much reform is necessary in the nomenclature of clays, as at present there is no agreement as to the precise meaning of "clay," "clay substance," and other terms.

"Primary clays" (i.e. those found near to the place of formation by rock decomposition) are usually lean or deficient in plasticity. "China clays" (Kaolins) are of this kind.

Under the action of water and other geological agencies, these slightly plastic primary clays may be ground, carried about from one place to another, undergoing purification or contamination in the process, until they are finally deposited in a more plastic condition in beds or seams, when they form secondary deposits as surface-clay, bed-clay, shale, fire-clay, boulder-clay, etc.

The degree of purity of a clay deposit must depend on the nature of the treatment it has received since its first formation by the breaking down of the felspar rocks which are, as far as is known, the original sources of all clays.

Red clays are those which have been formed from felspar rocks rich in iron oxides, or which have taken up this substance during their conversion into plastic clays.

When no more than a very small proportion of iron oxide, lime, magnesia, and alkalies is present a fire-clay or kaolin is produced and burns to a white or cream colour according to the proportion of colouring oxide present.

The exact processes which occur in the formation and deposition of clays is only of secondary interest to the brick and

tile maker; he has to deal with the clay deposits at his disposal, and has no control of their formation. It is very important, however, that he should know a little of the origin of any deposit he is called upon to work, or about which his opinion is being asked, as clay deposited by rivers must usually be worked differently from that deposited in a lake, the water from which has afterwards disappeared.

As the primary clays (kaolins) are often very pure, they are not usually employed for brickmaking and need not be considered at present, though some makers have found considerable profit in utilizing the waste material produced by the washing of these clays.

The secondary clays may be divided into three groups: (*a*) river deposits (fluviatile); (*b*) lake deposits (lacustrine); (*c*) sea deposits (marine).

River Deposited Clays.—River deposited clays are in beds of small sizes and of very irregular thickness; they are formed by the particles of decomposed rock carried along by the river settling out when the speed of the river is reduced, as at the bend of the river. They are usually rich in fossils, and it is not unusual for them to change in character very frequently. Thus the necessity of working a relatively large area of only a small depth is a great disadvantage in the production of the best qualities of bricks and tiles from this kind of clay.

In spite of this, the clay deposited by the Thames has been very largely used for brickmaking in the neighbourhood of London, and the lower deposits of clay made by this river reach as far as Leighton Buzzard and Seven Oaks respectively, and even beyond.

The difficulties of working river clays are particularly well shown in the case of the London clay, of which it has been said with much truth that "London clay inevitably spells ruin to the brickmaker not thoroughly familiar with its nature, for it is too strong to be used alone and no non-plastic material suitable for mixing with it (grog) is found in its neighbourhood. Yet when properly worked, no bricks can withstand the trying conditions of the London atmosphere as well as 'stocks' made from London clay." A study of fig. 1 will show that great care is needed to ensure that the clay used is really London clay, as it is very easy to confuse it with others which possess the same soapy shell-shaped fracture as the dried London clay, though they are really quite different and must be treated separately.

In addition to the shallowness of the deposits, the stones found in clays of this kind often cause serious trouble, and altogether the working of fluviatile clays is less certain, more complicated, and far less profitable than the use of the lake deposits or marine clays.

The rapidity with which rivers change their beds produces so great a variety in the nature and composition of the clay deposits that it is quite usual to find in neighbouring brickyards clays which have been deposited by the same river, but which are entirely different in their origin, nature, and properties. On this account methods of treatment which may be successfully employed in one yard may be quite unsuitable for another near by. This is a matter which must never be overlooked by the brickmaker.

Boulder-Clay has been produced in a similar manner to river

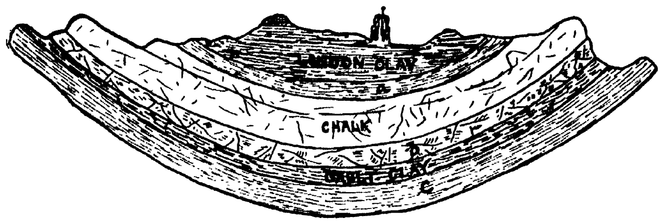

FIG. 1.—Diagrammatic section of London clay formation.

clays, but the river has been replaced by a glacier; it is usually seriously contaminated with sand and stones of a limy nature, and is difficult to work satisfactorily into other than common bricks.

Lake Deposited Clays.—Clays of lacustrine origin are in many ways similar to those deposited by rivers, but when extensive (as is usually the case) they are easier to work, because the deposits of differing composition may be more accurately mixed or separated.

Some of the most typical lacustrine clays are those of the Isle of Wight; unfortunately their situation and shallowness greatly detract from their commercial value.

The Reading mottled clay, which also occurs in France, is the product of another lake.

At Bovey Heathfield, near Newton Abbot, lacustrine clays of perfectly regular character occur and are over 150 feet deep, but this is exceptional in England.

Sea Deposited Clays.—The extent of marine clay beds is almost incredible, as they often stretch for hundreds of miles with a depth of thirty feet or more throughout the entire area. Their composition is remarkably uniform, and consequently they possess innumerable advantages over other kinds of clay.

The impression that they contain salt in excessive quantities is quite erroneous.

The fact that these marine deposits are almost free from fossils and remains of the higher animals points to their great antiquity, and the presence of sea-shells clearly indicates their origin.

Good marine clays, of which the famous Oxford clay is the best known in this country, cannot be but highly appreciated, but marine deposits of certain compositions can never be used satisfactorily. Many such deposits are rendered entirely useless by the excessive quantity of lime ("shell") they contain, whilst others are so excessively plastic as to be unusable without the addition of some non-plastic material, though this latter is seldom found near them, and the present prices of ordinary bricks will not permit it to be made by calcining raw clay.

Rock Clays are those which have been compressed owing to their situation, and are properly known as shales, slates, and fire-clays. The great compression has resulted in the consolidation of the clay, so that it has to be broken down either by the weather or by mechanical means before it can be used. Such clays are not found plastic, but become so on grinding and mixing with water.

Shale is the general name given to clay rocks which are laminated, and so split easily into thin layers. They vary in hardness and in colour, and are usually moderately pure. Some of them, being rich in iron, burn to a red or blue colour, whilst the pure ones (fire clays) are buff coloured when burned.

Most shales contain a small proportion of carbonaceous matter which is expelled on heating. In some cases, as at Peterborough, so much of this matter is present as to render the use of coal or other fuels in the kilns almost unnecessary. Many shales are seriously affected by the presence of nodules of pyrites, marcasite, and allied compounds of iron, which form spots of fair size in the fired goods and so spoil their appearance.

Shales are commonly found near the coal deposits, particularly in the North of England, and often extend to enormous depths. The Accrington shale is particularly famous, the analysis given of a shale from Whinney Hill, Accrington, being typical:—

Silica	61·46
Alumina	24·84
Protoxide of Iron	5·59
Sesquioxide of Iron	1·30
Lime	·60
Magnesia	2·42
Combined Sulphuric Acid	·23
Alkalies	·32
Organic Matter and Water	3·24

This shale produces fine red facing bricks.

Slate is really a compressed clay, but owing to impure composition cannot usually be made into bricks, though some slates which are worthless to builders may produce good common bricks.

Knotts Clay.—Near Peterborough (which is situated on the Oxford clay already mentioned) Knotts clay is found. This clay is highly valued; it has all the characteristics of shale and is rich in combustible matter, whilst its enormous depth and area, together with its regularity and composition, enable it to be made into bricks and fired at less than the cost of the fuel alone for bricks in some other parts of the country. The clays on the east and south of Peterborough can be most cheaply worked by the semi-plastic process, and everything is in favour of their being used for the production of a common brick at a remarkably low price.

Fire-clay is found throughout the coal measures. That in the neighbourhood of Stourbridge is highly prized, but carefully selected materials from North Wales, North Cumberland and Durham, Teign Valley in Devonshire, South Yorkshire and Derbyshire, Leicester, and the district around Glasgow, Kilmarnock, etc., in West Scotland, are equally satisfactory as refractory materials. The Irish fire-clays are usually of inferior quality.

The composition and qualities of fire-clays vary very greatly, and many varieties are known. The best type of fire-clay contains almost as much alumina as silica, but in the North of England the fire-clays used contain nearly twice as much silica as alumina. The highest grades of fire-clay are difficult to work on account of their low plasticity, but highly refractory clays which are at the same time plastic are very valuable on account of their scarcity. The fire-clays from the Midlands and Devonshire are specially noted for their suitability for the manufacture

of salt glazed sanitary goods. Those of Northumberland, Yorkshire, and West Scotland, have an equal importance in the manufacture of sanitary ware and glazed bricks. In the south of Yorkshire a material, corresponding to silica, with about 10 per cent of plastic clay and known as "ganister," is found in large quantities. Similar material is found in Dowlais (Wales), and Gartcosh (Scotland). The best ganister contains from 87 to 96 per cent of silica, with 4 or 5 per cent of alumina.

A more highly siliceous material is found in various parts of the country, and especially in the Vale of Neath in Wales. This is used for the manufacture of Dinas or silica bricks. It is not a clay, strictly speaking, but a powdered rock consisting almost entirely of quartz, though the term "clay" is often applied to it in the places where it is found.

The value of a refractory clay consists in the possession of particular characteristics. It may best be ascertained from a consideration of its behaviour in the following directions reproduced here from "Modern Clayworking":—

(*a*) Its resistance to high temperatures.

(*b*) Its resistance to pressure at high temperatures.

(*c*) Its non-absorptive power at any temperature.

(*d*) Its uniformity in size and composition.

(*e*) Its expansion and contraction due to heating and cooling while in use.

(*f*) Its resistance to the cutting action of the furnace flame, to the abrasive action of molten metal, and to the searching action of certain slags and metallic oxides.

(*g*) Its resistance to the reducing or oxidizing atmospheres in the furnace.

(*h*) Its resistance to ordinary wear and tear and to accidental blows.

It is, however, seldom that all these conditions can be realized at once, and that clay should be chosen which combines the most advantageous characteristics. Thus, a good second-class clay made up into bricks of a uniform size, of sufficient hardness, with low contraction and highly infusible, would be far preferable in practice to one which might have a lower percentage of alkalies and was, therefore, less fusible but lacked some other qualities.

Most of the above characteristics must be ascertained by a practical test, made for the purpose, but some of them can be determined by observation and analysis. Usually, the actual

value of a refractory clay can only be ascertained as the result of an extensive series of tests, which must be of a chemical as well as a physical nature.

Fire-clays burn to a white or cream colour, though some of the less pure ones are reddish in tone.

THE COLOUR OF BRICKS.

When heated, clays change their colour and produce bricks which may be white, cream, brimstone yellow, dark yellow, buff, red (terra-cotta), brown, black, blue, grey, or any combination of these colours. The tint produced depends on the composition of the clay and the nature of the heating.

White Bricks.—A perfectly white brick is practically unknown, as it requires the use of clays of such purity as to make them too expensive for this purpose. When the effect of perfectly white bricks is required it is usual to cover bricks of inferior clay with a mixture of better quality which will produce the required results. This process is known as "bodying" (see "glazed bricks").

Suffolk Bricks and others of whitish colour may be produced by making mixtures of certain clays and chalk, or by using such mixtures of chalk and clay as occur naturally in some districts and are known as marls.

Gault beds are of this character and contain about one-third of their weight of chalk. They are chiefly used in conjunction with other clays for the production of the "white Suffolk" brick already mentioned. Similar bricks may be made by the addition of a sufficient quantity of chalk to almost any red-burning clay.

Marls or *Malms* are clays that have become mixed with chalk or limestone during their formation, and form one of the most important sedimentary deposits. In South Staffordshire and in some other districts the term "marl" is incorrectly used to indicate clay or brick earth. True marls always contain chalk.

In Nottinghamshire and in some other districts, clays are formed which contain so little chalk that they produce excellent red bricks. In such cases it is preferable to consider these as mild clays, though the local brickmakers invariably speak of them as marls. The local name is correct so far as the general clay deposits are concerned, as these turn to a creamy white, or to a dirty straw colour, but should not be applied to the red-burning clays in those districts.

If the chalk and clay are in the correct proportions, the marl may be used at once for brickmaking. This is, however, seldom the case. Marls which are deficient in clay must have some clay added, and those which are deficient in chalk must have this material added in a finely powdered condition. The mixing of the ingredients is usually effected by treating each separately with water, reducing the whole material to a slip or slurry, and mixing these liquids in the correct proportions. The mixture is then allowed to settle until, either by running off the water or by evaporation, a marl of the proper consistency is obtained.

The chalk diminishes the contraction of the clay during the drying and burning; it also acts as a flux, producing a much stronger brick than would otherwise be the case, and, in addition, it forms a white or cream coloured compound with the iron oxide in the clay, and so produces a brick which is nearly white in colour. In some cases the proportion of chalk or similar material in these clays is large and not in a very fine state of division; the bricks made from it will fall to pieces on exposure, owing to the presence of uncombined lime in them which "blows" and disintegrates the bricks containing it.

The amount of chalk which may be present in the marl or mixture used for brickmaking should not exceed 25 per cent, and if the original marl contains more than this (as is often the case) sufficient clay must be added to reduce the chalk in the mixture to this proportion. In many cases bricks should not be made from marls containing more than 12 per cent of chalk, and for red bricks not more than 5 per cent should be present. White bricks (or the nearest to white commercially obtainable) are chiefly made in Devonshire, Dorsetshire, Cambridgeshire, Norfolk, Suffolk, and Essex.

Yellow Bricks are made in the neighbourhood of London and in all other places where the clays found are suitable for brickmaking, yet do not contain sufficient iron to produce a red brick, though in some cases the natural colouring effect of the iron is obscured by the presence of chalk or lime compounds, as in the marls just mentioned. The precise shade of yellow produced depends on the proportion of impurities in the clay and on the nature and extent of the firing.

Red Bricks are produced in almost any part of the country. Some of the finest reds are made in Leicestershire, Hampshire, and Berkshire, Ruabon, and Accrington in Lancashire, but

sufficiently pleasing shades of reds are obtainable with care with clays in many other districts. The chief substance to which the red colour is due is the iron oxide in the clay, and to produce a pleasing shade of red a clay must contain at least 4 per cent of this material, and must be nearly free from lime compounds which would detract from the colour. The addition of iron oxide to clay to improve the colour is seldom satisfactory.

Bagshot clays are well known for the excellent red colour of the bricks produced from them. The Oxford clay burns to a lighter tint. With Midland and Western clays almost every variety of shade can be obtained. Most surface clays can be burned to a good red colour, though there are some notable exceptions.

Many shales also produce bricks of a fairly good red colour, but the sources of red-burning bricks are so numerous as to make a complete list impossible.

Red-burning clays are popularly divided into two classes, " strong " and " mild " or " loamy ".

Strong clay is highly plastic and, in a certain sense, may be regarded as pure clay. It is generally free from stones, sand, chalk, or other non-plastic material, and is liable to crack and become misshapen in the kilns and to shrink excessively. This difficulty may be removed by mixing it with sand, crushed rock, grog, ashes, or other non-plastic material in order to open it and diminish the shrinkage.

On account of its plasticity and stickiness, strong clay is very difficult to work, but with sufficient non-plastic material available it usually forms an admirable brickmaking material. Without this addition the attempt to work it is almost certain to end in failure. Unfortunately the typical strong clay near London is not found contiguous to suitable non-plastic material. It must, therefore, be mixed with ashes (breeze) in order to reduce its shrinkage, and to permit it to be more easily dried and fired. Strong clays when free from stones are referred to as " pure " by brickmakers, other strong clays are known as " foul " ; the latter are to be abhorred unless the brickmaker is unusually skilled or takes up the manufacture of bricks for other than commercial purposes.

Loams or mild clays contain a considerable proportion of gravel or sand, so that they are less liable to warp or shrink excessively than the strong clays.

When excessively sandy, the texture of the earth is so loose

that the addition of chalk or clay is necessary to bind the mass together, but when of medium plasticity the mild clays are among the best for brickmaking purposes. The majority of clays used for brick and tile making are of a mild character; others must be made so by the addition of suitable non-plastic materials. The term "loam" is commonly restricted to certain light sandy clays, the term "mild" clay being much broader in meaning. Highly sandy clays are particularly used in the manufacture of "cutters" and "rubbers," though these bricks are often made from more plastic clays to which a suitable proportion of sand has been added.

Terra-cotta is made from any fine red-burning clay, but the best varieties require material which has been many times deposited by natural causes in order that it may be sufficiently fine in texture; it must also produce a pleasant colour when fired. For terra-cotta work, clay should be moderately porous when burned, should contain sufficient flux to give it a slight natural glaze when fired, and should be sufficiently fine to enable the most delicate carving to be satisfactorily carried out.

The precise shade of colour produced by a red-burning clay cannot be foretold, as it depends so much on the state of iron oxide in the clay, the nature of the firing, and other conditions of manufacturing. Clays which burn to an unsatisfactory colour cannot, as a rule, be improved by the addition of iron oxide, as this material when artificially prepared never gives the same colour as when it occurs naturally in the clay. Attempts to improve the colour of red-burning clays must therefore be confined to the purification of the clay used, to the addition of other clays, or to an alteration in the method of firing.

At Ruabon, terra-cotta is made from a rock clay to which one-third of its weight of brick dust is added.

Where terra-cotta is required to be of a buff or cream colour most fire-clays may be used in its production, but the most suitable terra-cotta clays are those near Poole, Tamworth, Ruabon, and in Devonshire; smaller deposits being found in many other parts of the country.

The term "terra-cotta" usually applies to objects of a certain shade of red, but originally it was used for all kinds of baked earth. At the present day any vases and similar objects made of unglazed clay are classed as "terra-cotta" by dealers, quite irrespective of their colour.

As the best terra-cotta clays occur in only a few localities,

many manufacturers prepare artificial mixtures which they grind to the requisite fineness.

Brown Bricks.—Brown bricks are made of clays which have a different composition and texture to red bricks, though in many respects they are very similar. Many impure shales, for example, contain so much fluxing material that they vitrify before the temperature is reached at which the full red colour of the iron oxide is produced, and consequently a brown brick of more or less pleasing appearance is produced. Some red bricks which are over-heated also produce a brown colour.

Blue or Black Bricks are chiefly made in Staffordshire from a clay very rich in iron oxide. When under fired they are reddish in colour, the blue being only developed at a high temperature. In Germany and some other parts of the world where no clay suitable for blue bricks is to be found, artificial means are employed to produce the colour; these are not so satisfactory as bricks made from the Staffordshire clay. Staffordshire blue bricks are partly vitrified, extremely hard, and with a glazed surface. They are almost invariably used where great strength is necessary, and are very highly thought of for engineering purposes.

The material used in Staffordshire for the production of blue and red bricks is a friable kind of clay which is heated to such a temperature as to bring about a partial vitrification and reduction of the iron oxide. Marls and clays suitable for brickmaking are very abundant in Staffordshire, and a most extensive bed of red "marl" runs in an almost unbroken line from north to south throughout the county.

Grey Bricks are of two kinds, this term being sometimes used for a variety of blue bricks and sometimes for a kind of red-burning brick, the colour of which has not been fully developed, or which has been hidden by a kind of "scum," as in the grey bricks of Lancashire.

GENERAL CHARACTERISTICS OF BRICKS.

A thoroughly good brick should be regular in shape, texture, and colour, equally and perfectly burnt throughout, and should be free from all cracks and flaws—even though they be hair-cracks—sharp in the arrises, and should give out a clear ringing sound when struck either with a stone, another brick, or a piece of metal. For many purposes, however, it is unnecessary to insist upon all these qualities, any hard and well burned brick

will suffice for foundations and internal work which is to be subsequently covered; and for such purposes rougher and cheaper bricks are frequently the more useful, affording a better key for plastering than those with a smooth surface, and often being better weight carriers than soft, well-finished, facing bricks.

Sandy and absorbent bricks should not be used in foundations, nor in external walls likely to be exposed to water or driving rain. Such bricks are generally soft and do not weather well, being frequently under-burned; and by retaining moisture they encourage the growth of lichen and climbing plants, which all gather and retain damp.

Soft, under-burned bricks are valueless. No brickmaker with a reputation to lose will sell them, preferring to pass them through the kiln a second time, or to crush them for sand or grog. On the other hand, a remarkably non-absorbent brick, heavily pressed and highly burned, may have too smooth a face to adhere readily to mortar, especially in summer time, in spite of a good wetting.

Over-burned bricks will melt and run together forming "burrs," which are useless except to be broken up for road metal or concrete.

Faulty bricks are more often met with amongst those which are hand made, hack dried, and clamp burned, than amongst those which are machine made, chamber dried, and kiln burned. To give a complete list of all the different kinds of bricks now made in this country is almost impossible. But the following are the most important when bricks are classified by their (1) colour, (2) place of origin, (3) method of manufacture, (4) use, (5) quality. The various colours of bricks have been mentioned on page 8. It must be remembered, however, that in different localities the colour may be known by a different name, and bricks of different colour are often classified as if they were all of one shade, so that sorting them on a basis of colour alone is not always satisfactory.

The place of origin of bricks and tiles is also misleading in many cases, because the successful use of these goods from one locality often leads to their imitation by firms in other districts, and it is becoming customary with certain classes of goods to name them after the place from which such bricks were originally produced, though the particular samples offered for sale may never have been near to it. Goods which are classified according to the place of origin are easily recognized, as most

of them bear some title and imprint upon them. In many cases they are specified under the name of the district from which they are supposed to come, as Flettons, Accringtons, London stocks, Bath bricks, etc.

Fletton Bricks, sometimes known as "Flettons," are made by the semi-dry or semi-plastic process from clay found in the neighbourhood of Peterborough. The quality and colour vary greatly, but as the bricks are cheap, and generally used where colour is unimportant, they command a good sale. The best are of a good red colour, but most of them have a yellowish tinge; they are very smooth on the surface, and it is sometimes found that plaster will not adhere to them satisfactorily.

Bath Bricks are made near Bridgwater, in the West of England, from a very siliceous clay, they are only slightly heated and are not used for constructional purposes.

Accrington Bricks have gained a high reputation for their red colour and strength, and *Leicester bricks*, together with those from many other districts, have a more local reputation for size, colour, and strength.

London Stocks are made for many miles round London, but the term "stock bricks" is used in many other parts of the country to denote the particular kind of brick made for general use in any district. The London stock brick is coarse, hard, and strong, with a grey, yellow, or, occasionally, red colour. They are frequently cracked superficially, and are very irregular in structure and colour, but if well burned are excellent for general purposes, being partly vitrified and stronger than their appearance would indicate. London stock bricks are classified locally under a number of different terms according to their quality.

Under methods of manufacture may be placed:—

Dry-Dust Bricks, made as the name indicates from powdered clay without any addition of water. This method is not often used for bricks, though very popular for tiles. The material must contain sufficient flux to bind the particles together during firing.

Semi-Dry or Semi Plastic Bricks are made from material which is almost but not quite dry. This method of manufacture has for some time been very popular on account of the cheapness with which it enables bricks to be made, but it is now being replaced by the stiff-plastic process. The most important centres of semi-dry or semi-plastic bricks (the terms are identical in meaning) are Accrington and Peterborough.

Stiff Plastic Bricks are made from a paste which is worked through machines in as stiff a condition as possible, so as to save time and expense in drying the bricks. This method of manufacture is rapidly increasing in popularity.

Plastic Bricks are those made from clay which has been converted into a highly plastic paste, or in which the plasticity has been developed as fully as possible. All hand-made bricks and tiles are of this kind, but the term is also used in connexion with machine-made goods, particularly with loamy clays. The main difference between this and the stiff-plastic process is the greater quantity of water added to the clay, which necessitates thorough treatment and more careful drying.

Sand-Faced Bricks are largely used in the South of England for exterior work. They are characterized by a good red colour which is very even in tone, but are soft and highly absorptive on account of the clays from which they are made. The name is derived from the mould being sprinkled with sand to prevent the clay from adhering to it, instead of using water for this purpose as in slop-moulded bricks. Incidentally the sand, if properly chosen, produces an improvement in the colour of the bricks. As a rule they are not very durable, and only those which "ring" well should be used for best work. When really well made they are in every way excellent for buildings in the country and smaller towns.

Marl Facing Bricks are those made near London to be used along with stocks, to which they are distinctly superior for outside work.

Rubbers and *Cutters* are soft bricks made from sandy loams, and will bear cutting and rubbing to any required shape. They are used for making bricks of special shapes for arches, carved work, etc., being cut or rubbed down after the completion of firing (usually on the building site). Consequently, they must be of the same colour throughout and should be of such a nature that the interior as well as the exterior of the brick can resist the weather. White, red, and buff rubbers are made, though the red ones are most popular.

Slop-Moulded Bricks are made, as the name indicates, from a soft paste or "slop". They are necessarily hand made, the mould being wet with water to prevent the clay from sticking to it, instead of being covered with sand as in the manufacture of sand-faced bricks.

Pressed Bricks are those which have their final shape given to

them by means of a press, but the term is also used for most machine-made bricks. They are usually heavier and denser than hand-made bricks or "wire-cuts" and are often perforated, or provided with "frogs" to lessen their weight. Pressed bricks should be perfectly uniform in size and shape and should have a smooth surface and arrises. They usually require great care in drying and in manufacture generally, but are certainly the most accurately formed of all bricks and tiles.

Polished Bricks are not really polished, but are rubbed on an iron plate so as to produce a moderately smooth surface. They were originally made to compete with pressed bricks, but are now seldom seen.

Clamp Bricks are those which have been fired in a temporary kiln known as a "clamp"; they are usually irregular in shape, but are useful in many cases where a better grade of brick cannot be obtained, as in new districts and in the Colonies.

Glazed Bricks are those having their surface covered with a glaze so that they are more easily kept clean, or so as to produce a definite artistic effect. By the use of an intermediate layer of white or coloured clays between the brick and the glaze, beautiful decorative effects may be obtained.

The uses made of bricks gives rise to the following names amongst others:—

Fire-bricks are those made from clay with a great power of resistance to heat. They vary greatly in quality, shape, and size, and are chiefly used for furnace lining. Fire-bricks must be almost free from metallic oxides, and are usually of a pale cream colour. Low grade fire-clays are largely used for the production of paving bricks, sanitary ware, and building bricks.

Paving Bricks are chiefly made of a clay which vitrifies in the kiln, as it is found that such bricks have a greater resistance to traffic than more porous ones. They are blue or yellow in colour and are sometimes known as "clinkers".

Clinkers are small, well-vitrified bricks used for paving. In this country they are commonly yellow in colour, but the same term is used for any vitrified brick.

Engineering Bricks are used in the construction of railways, bridges, and other civil engineering work. They must be of great strength and durability, and are usually vitrified and "ring" well. The blue bricks from Staffordshire are used in enormous quantities in this way.

Floating Bricks are of little practical use, though apparently

popular among the ancients. These bricks were made of a special fossil earth (found in Italy) and weighed only about one-fourth as much as clay bricks of an equal size, whilst their strength is the same as common hand-made bricks. In recent years light-weight bricks have been made by the addition of sawdust to the clay and by making the bricks hollow.

Channel Bricks, Air Bricks, Plinth and Coping Bricks, derive their name from the uses to which they are put; they must be made in special moulds, and so resemble terra-cotta work rather than ordinary brickmaking.

Squints, Jambs, Bullnoses and Other Terms are used to denote special shapes.

The qualities of bricks are responsible for the following terms:—

Malm Bricks, which are best quality hand-made bricks produced from marl; they are of a yellow colour.

Seconds and Thirds are bricks sorted from contents of the kiln after the best bricks have been removed. "Seconds" are much used for work for which the best quality of bricks is not necessary; seconds bricks are not good enough in shape or colour to be used as facings.

Stocks are the average quality of bricks made in any district, but the term is mainly used for a certain quality of London bricks.

Washed Stocks are a low quality of malm bricks.

Grey Stocks are good bricks but irregular in colour, so cannot be used for facings.

Rough Stocks correspond to "thirds," and are not suited for good work on account of their irregular shape and colour. For foundation work they are very satisfactory, being usually hard and sound.

Place Bricks are only a low grade of brick, used chiefly for temporary purposes.

Grizzles are insufficiently durable for outside work, but find a use in interiors and partitions.

Shuffs and Shakes are unsound bricks and should not be used.

Bats are rubbish, being the residue left when all the saleable bricks have been removed from the kiln.

Crozzles are bricks which have been so over-heated in the kiln that they have become vitrified and have adhered to each other. They are badly shaped and of little value, being included in the "bats" in the South of England.

SAND, BREEZE, AND OTHER MATERIALS.

As already mentioned, it is necessary with many clays to use non-plastic material in order to produce a satisfactory brick earth. The following are the materials most frequently employed for this purpose :—

Sand, like clay, is a product of decomposition of rocks, but when of good quality consists almost entirely of silica.

For mixing with clay, sand need not be pure so long as it is free from undesirable matter.

When used for moulding bricks (in the hand-making process) the colour of the sand when burned is important. The finest Bagshot sand is considered to be the most suitable for red-burning bricks, and great pains are taken by brickmakers of good reputation to secure a satisfactory material.

A white-burning sand is used for buff and white bricks and is of the Calais sand type. It must be fairly free from iron oxide and in a very finely powdered condition.

Coarse, sharp sand is useless for moulding, though often valuable for mixing with the clay.

Soil, as a brickmaking material, is only used in the neighbourhood of London. The clay in that district is so strong that it is necessary to reduce its plasticity, and "soil," being combustible as well as non-plastic, has special advantages for this purpose. "Soil" is the fine material obtained by sifting domestic ashes or cinders, the coarser parts (known as "breeze") being used for fuel. The "soil," in addition to reducing the contraction of the bricks, produces a special colouring, not otherwise obtainable, and attributed to the impurities (sulphur compounds) which it contains.

"Soil"—meaning surface-clay or loam—is quite a different material, and is usually unsuitable for brickmaking, though in some districts it is successfully employed. Most brickmakers find it necessary to remove the top layer of earth ("soil") and to discard it. This operation is known in some districts as "encallowing".

Grog is, strictly speaking, clay which has been heated sufficiently to destroy its power of becoming plastic and has then been reduced to a powder. The term is, however, conveniently applied to ground bricks or other waste from a clay works, which is mixed with raw clay in order to produce a mixture in which the amount of contraction is within convenient limits. In

this country, grog is seldom prepared by calcining and grinding clay, but on the Continent several firms make a speciality of the manufacture of this material, which they supply under the trade term "chamotte". For most purposes fire-bricks, which are of too poor a quality to be offered for sale, may be ground and used as grog, but for the manufacture of the best fire-bricks it is desirable that a special grog should be prepared. The use of this material is described more fully in the Chapter on "Fire-bricks".

Chalk is found in such enormous quantities that it is readily procurable by those brickmakers who require to add it to their clay in order to form an artificial marl (page 8). For this purpose the chalk must be freed from stones and pebbles, and is generally washed in a special mill similar to that used for washing clay. Chalk, being harder, requires a preliminary crushing, though the inclusion of heavy wheels with spiked rims in place of two of the hurdles of the wash-mill is usually found to be efficient.

Water is a material of great importance to the brickmaker, and if much difficulty is experienced in obtaining it cheaply the yard cannot be a success. For most brickmaking purposes the purity of the water is of small importance, but sea-water must be avoided on account of the salts it contains. Other water rich in salts must be avoided for the same reason, as it would produce a scum on the surface of the goods during drying. For use in boilers, water should be as pure as possible, and facilities for collecting rain and other surface-water should be provided. With a little provision in this way it is often easily possible to procure ample supplies of pure water at little or no cost, and the saving effected in the cleaning of the boilers is an item well worth consideration at the present time.

Hard Water should be avoided in boilers unless it is softened before use. There are many arrangements now on the market whereby this softening may be effected. Most of them are unnecessarily costly for the brickmaker's purposes. The best water-softening agents are (in order of merit): (1) baryta, (2) lime in conjunction with soda, (3) caustic soda and tan liquor. Hard water should be fed into a large tank, treated with the softening material, and allowed to settle before it enters the boiler.

Rain-water and surface-water need no treatment as they are practically pure, though occasionally a little soda is necessary in order to prevent corrosion from slight traces of acids sometimes contained in them.

CHAPTER II.

THE GENERAL MANUFACTURE OF BRICKS.

THE clay which is thought suitable for brickmaking having been located, it is necessary to decide on the best method of working it, if good quality bricks are to be produced. The composition of the clay varies so greatly in some districts that it is impossible to decide which is the best method of brickmaking unless the characteristics of the clay are well known.

Practically speaking, several methods of brickmaking are possible, according as the clay requires a smaller or larger quantity of water to be mixed with it; if no water at all is used, the semi-dry or dry process may be employed, although in many cases a better quality of brick will be produced if the plasticity of the clay is developed by the addition of water and subsequent treatment in the mixer. When only a little water need be added, the stiff plastic process may be used, and where more water is necessary the clay must be made thoroughly plastic and may then be shaped either by hand or by machinery.

Clay is obtained from the pit or quarry, as the case may be, by digging or blasting, or by any of the improved methods of mining. As in most clay deposits the composition of the bed varies at different parts, it is necessary to exercise much care in choosing portions of the bed from which the clay has to be taken. It is, therefore, usual to work horizontally in a series of terraces or steps, each step being the height of the particular strata worked, but conditions vary so in different deposits that each brick manufacturer must, to a large extent, be left to use his own judgment in the matter. Care and attention are required if the clay hole is to be worked economically, as otherwise a large amount of useless material may be shifted. Water in the clay hole is often a source of trouble, as its removal entails considerable expense. For most purposes a "Pulsometer" pump is the most suitable, as it can deal with very dirty water and has no wearing parts. When steam can be carried to the

clay hole this pump is particularly suitable, otherwise some form of diaphragm pump should be substituted. The ordinary types of pump, whilst excellent for clean water, are not desirable for use in clay holes.

Special oversight is needed to prevent the wrong strata becoming mixed with those containing suitable material, particularly at certain stages in the quarrying, but with capable men no special difficulty in this direction need be experienced.

In a few instances it is sufficient to work straight forward without any attempt to separate the impurities occurring in the clay. It is then wise to use a steam-navvy or other mechanical means of obtaining the clay, as with such appliances the cost of getting it is greatly reduced. Steam-navvies are useless where much sorting of the clay has to be done, and cannot be used in the coal mines from which certain shales and fire-clays are obtained.

Digging should, when possible, be paid for "by the piece". This is very advisable because it enables the men to earn more per hour than day wages if they should wish to do so; yet, whilst keeping the cost of digging at a figure agreeable to the employer, it enables them to do something in very bad weather. In the latter contingency an employer would stop his men entirely if employed by the hour, whereas on piece-work the men can earn something if they are so minded. The only danger in "piece-work" is where careful sorting of the clay is necessary and the men are tempted to send unsuitable material to the mills. In paying "by the piece" the labour may be classed in two sections: (1) digging and filling barrows or wagons, (2) wheeling to the heap.

Easy, flat digging and filling is worth as a rule about 4d. to 6d. a cubic yard, but this item varies according to the hardness and accessibility of the clay. Wheeling away usually costs about 1½d. per run of 20 yds. There is also the expense of untopping or encallowing a clay bank, putting in and shifting "roads" on which to wheel, and frequently of sorting out and getting rid of useless veins of earth. It is seldom that earth can be got on to the heap for less than 1s. per yard all told, or 2s. 9d. per thousand bricks, and it is in this that the hand maker is at a disadvantage compared with the makers of those Midland clays which are uniform to a great depth. The standard price for loading by hand into the hoist wagons is 1s. per thousand, but when a steam-navvy is used, less than half these figures will

suffice. In yards which only work for a portion of the year, the clay is usually dug out in the autumn when the brickmaking has ceased. It is then all heaped up and left to be mellowed by the winter weather and especially by the frost, during which operation the clay is completely broken up. Once or twice in the winter the heap may be turned over with shovels, so as to expose it more thoroughly, and to enable stones to be picked out as far as possible. This exposure of the clay is known as "weathering".

The thickness of the layers of clay on the heap should not be too great, as the frost will seldom penetrate to a depth of more than 8 in. On this account it is desirable to use a definite area of ground for exposing the clay to be weathered, and to cover this all over to a slight depth and repeat the covering as often as possible, instead of tipping the clay into a heap in the ordinary way. Sometimes the clay will be sufficiently broken up by very slight exposure to the air, and in some instances summer heat is quite as efficient as frost. The object of the weathering is the separation of the particles from each other so that they may more readily become plastic and produce a mixture of even composition when worked up with water. It is not only the powerful mechanical action of frost which is so beneficial in weathering. The mechanical actions which take place are often extremely valuable, and some clays which are almost unworkable when freshly dug, will be found to produce first-class bricks after the clay has been exposed for as little as forty-eight hours to the air. This aspect of weathering deserves more attention than it has received hitherto, and quite a number of brickmakers would find it well worth their while to crush their clay and spread it in the open air for a couple of days before proceeding to use it.

The getting of fire-clay from underground mines forms a special branch of mining, and must be studied from textbooks devoted to that subject. It is beyond the province of the brickmaker, who usually purchases such clay delivered at ground level.

Whilst some clays are found in a state in which they can be made into good bricks without any purification, there are many others which must undergo a preliminary picking or cleaning before they are fit to use. Many clays are so contaminated with impurities that much difficulty is experienced in working them. The Midland marls and shales are always troublesome on account

of the veins of impure limestone ("skerry") which they contain, and which tends to make the bricks "blow" on exposure. Other clays are contaminated with gravel or other material which must generally be removed before they can be used.

It will readily be understood from the above that the treatment a clay must undergo will depend upon its nature, the impurities it contains, and the purposes for which it is to be used. Three chief methods of treatment are possible: (1) It may be used direct; (2) it may be mixed with some other material; (3) it may be picked, washed, or otherwise purified before use. The first method is to be preferred when it is practicable, though it can only be used for certain clays. The second method is frequently employed (especially in the manufacture of fire-bricks and other special work), and in the South of England in connexion with "malming" or adding chalk.

The material to be added may be almost any mineral of a non-plastic nature which will not spoil the bricks and which is sufficiently cheap. In the real "malming," chalk is invariably used, but in some districts the clay is reduced in strength, and made easier to work by the addition of sand or some other siliceous matter. In the neighbourhood of London, "soil" is mixed with the clay for a similar purpose, and not only assists the drying of the bricks but aids their burning. The third method includes two entirely different modes of treatment (*a*) removal of stones or other obvious impurities, and (*b*) washing.

To separate large stones, or unsuitable materials of a rocky nature, the clay must be examined carefully and the undesirable constituents removed by hand. Thus, the larger pieces of rock may readily be removed from boulder-clay and large nodules of pyrites, etc., from fire-clay, by this means, though pebbles of less than one inch diameter are usually too small to be thus separated. From some clays the smaller stones may be separated by mixing the material into a paste with water, and compressing it in a drum with perforated ends on sides. The clay passes through the perforations leaving the stones inside the cylinder. A number of appliances for this purpose (known as "clay purifiers") have been placed on the market and have met with considerable success on the Continent. The most popular one in this country is Whitehead's perforated pug-mill. It consists essentially of a pug-mill which mixes the clay into a paste, and forces it through the perforations in the cylinder, the stones being discharged through an aperture in the base of the machine.

A simpler appliance for the same purpose consists of a long drum of perforated steel open at both ends and fitted with a pair of pistons which work in opposite directions alternately. One piston is fixed at one end of the drum and the latter is filled with clay paste. The second piston is then inserted and is used to compress the material. The clay exudes from the perforations, and by the time the piston reaches the farther end of the cylinder only stones remain behind. The first piston is now withdrawn, and the second moved forward driving the stones in front of it, so cleaning the drum. This appliance suffers from the disadvantage of not working continuously, but for small yards it is often useful, and is less costly to install than the more efficient clay purifier previously described.

Another form of clay purifier, which has met with great success in the working of Continental boulder-clay, is the invention of M. Bohn. It consists of a pug-mill with a perforated barrel

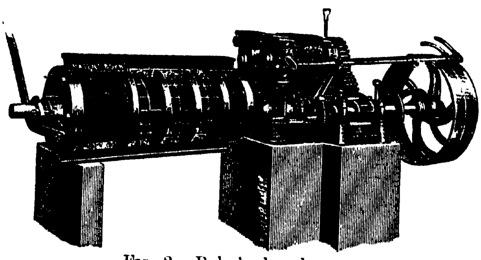

FIG. 2.—Bohn's clay cleaner.

and a partially closed end (fig. 2). The clay is delivered into the open trough of a mixer, and after being treated with sufficient water to make it into a paste is forced forward by the blades of the pug-mill. Under the great pressure exerted, the paste is forced through the perforations in the barrel, all the stones being forced out of an aperture in the end of the barrel along with some clay. This aperture can be closed partially or completely by means of the lever shown. In the most recent machines provision is made for adding water under pressure to the "stones" from which most of the clay has been separated, and in this way the remaining clay adhering to them is removed. The special feature of the machine is the construction of the barrel in small sections so that renewal of the perforated portions, as these become worn, is readily and cheaply effected. It is found in practice that perforations less than $\frac{1}{16}$ in. diameter are inadvisable in clay

purifiers, and consequently gravel and sand cannot be removed by their means. When it is necessary to remove these materials the clay must be washed.

Washing, or mixing the clay with a large quantity of water, is a simple and frequently used method of separating it from stones and other impurities. Chalk when used is also washed so as to clean it and reduce it to the necessary fineness to be properly mixed with the bulk of the clay. Some mixtures of chalk and clay in suitable proportions occur naturally, and are known as "real malms," but more frequently a certain amount of chalk is added to produce an artificial malm. The clay and chalk are usually washed separately in large circular tanks known as wash-mills. In the centre of this tank is a pillar with the lower part of brickwork and the upper of metal. This latter acts as the pivot on which is hung a horizontal frame containing a number of suspended harrows, or washing gates. The frame is rotated by horse or mechanical power (the latter for preference, as it is much cheaper), the circular tank being filled to three-fourths of its depth with water and the material to be washed, a thick slip or slurry is soon formed by the tearing action of the tines on the harrows on the clay. At suitable intervals the mill is stopped, and the slurry allowed to run out into settling tanks or wash-backs, stones and other undesirable matter remaining in the mill. After being filled and emptied three or four times the mill must be thoroughly cleaned out, though the frequency with which this operation must be performed depends upon the proportion of impurity in the clay. During the last twenty years several important improvements have been made in the design and construction of wash-mills, and it is now possible with some clays to work them continuously.

A modern wash-mill may conveniently be about 14 ft. in diameter, the framework revolving 9 to 10 times per minute. It will require about 7 h.p. to turn it, and will treat from 20 to 40 cub. yds. of material per day, the higher figure being reached with a fine clay or marl.

The wash-backs are usually constructed like shallow reservoirs by building earthwork walls so as to form a series of large ponds or tanks about 50 ft. sq. and 3 to 4 ft. deep. Each wash-back should be provided with a wooden or brick flue, the height of which can be altered to suit the level of the clay and water in the back. This flue leads to a drain, and serves to carry off the water when the clay has settled. The water should be returned

to the wash-mill and used again. A simple but effective flue consists of a wooden trough, sloping steeply ni the wash-back, the "top" of the trough being covered by a row of bricks which converts it into a "square pipe". By removing the bricks one at a time the water may be run off from the clay at convenient intervals.

As it is not always possible to arrange the settling tanks or wash-backs at a lower level than that of the wash-mills, the slip or slurry is often pumped out of the mill (plunger pumps being used for this purpose), and by fixing a comparatively fine screen to the suction end of the pump the necessity of emptying the wash-mill more than once every few weeks may be avoided, unless the clay is exceptionally impure. Even when no pumps are used, the outlet from the mill is best covered with an iron screen, so that all the larger particles may be kept out of the slip going to the settling tanks. It is often customary to drive the mill for a certain time and then to stop it whilst the liquid is run off. This wastes time and should be avoided when possible, a constant speed of output being generally preferable, and usually attainable.

In the simplest form of power-driven wash-mill the harrows are hung at each end of a pair of T-irons, each about 14 ft. long, by chains attached to the hooks, so that as the mill becomes partially filled with stones the harrows do not touch the bottom of the tank. To the centre of the T-irons is attached a horizontal pulley, the hub of which fits loosely over the vertical post in the centre of the mill. This pulley is driven from a chain from the engine, or, in the case of a horse-driven mill, it is replaced by a long wooden beam.

The harrows should be about 3 ft. sq. and each should have a dozen teeth, or tines, made of iron rods an inch square. In some yards instead of driving the mill direct from the engine it is connected to a special pulley from the pug-mill.

The chalk may be washed in a similar mill, but it is more usual to replace one or two of the harrows by a heavy spiked roller which more readily breaks down the lumps and enables the washing to be carried out more rapidly (fig. 4).

A sufficient quantity of slurry having been run into the settling tank, or wash-back, to fill it to a reasonable depth, a second tank must be brought into use, and the first left undisturbed until most of the water has risen to the surface; it must then be run off carefully by means of sluices at the side of the tank, until only a

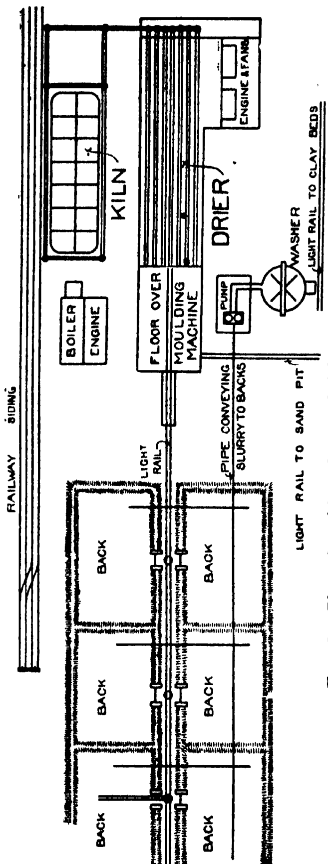

FIG. 3.—Plan of washing plant in brickworks (Middleton).

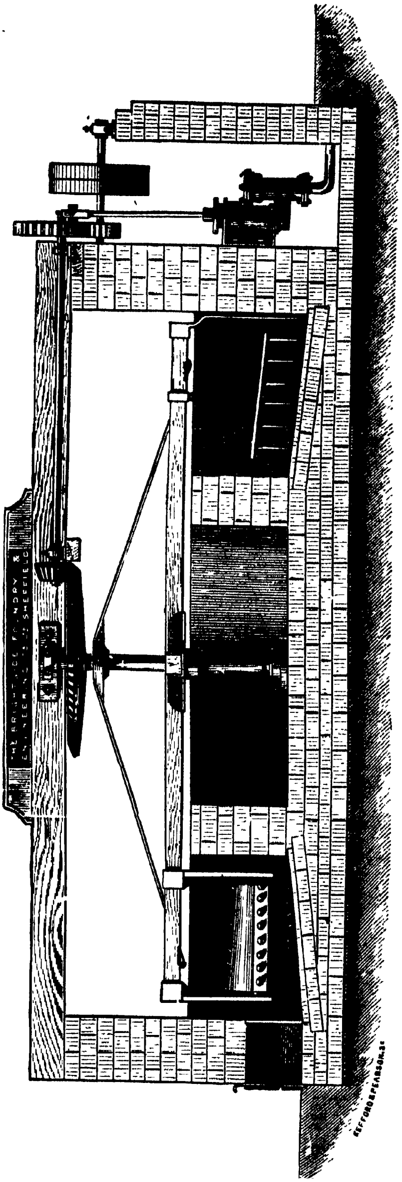

FIG. 4.—Wash-mill with chalk-crushing roller.

thick mass of paste is left. This must then be left till sufficiently stiff for a man to walk on it without sinking, after which men are sent to dig out the material preparatory to its further treatment. During the last period of stiffening it is desirable to cover the mixture with a layer of sandy loam, so that it may not become hard and leathery. In the south of England "soil" (cinder dust) is used instead of loam (page 18). The workmen should dig vertically, starting at one corner and working down one side of the tank, and should not dig out the clay in horizontal layers.

When a mixture of clay and chalk is used for brickmaking, the washing process is precisely similar to that described above, but the chalk should be mixed with an equal weight of clay before being washed, as if washed alone and then mixed with the clay it is difficult to avoid the formation of white specks in the brick. Instead of feeding the clay-mill with water only, slip from the chalk-mill may be added in proportionate quantity. As the amount of water used will be about 100 gallons for every cubic yard of clay, it is wise to return the water run off from the settling tank to the wash-mills instead of wasting it. In some cases, owing to the position of the tanks and the mills, a pump will be necessary.

It is a curious fact that most clays suitable for brickmaking by hand will pass through a sieve having 100 holes per running inch, when the clay is mixed with twice its weight of water. So fine a sieve can only be used for testing, but the moving water in the wash-mill acts as though the clay were passed through a sieve, and by keeping the speed of the mill constant at the proper rate a wonderfully fine separation of the clay from the other materials may be made. When clay and sand are to be mixed together, washing machinery is not resorted to, owing to the density of the sand, but the mixture is made in a wet pan-mill or in a pug-mill or similar paste-mixing machine.

It is customary when using malms (mixtures of clay and chalk) to add a certain proportion of ashes ("soil"); this is known as soiling. The ashes used are ordinary cinders collected by the dust-bin men and sifted so as to remove the larger pieces. The sifted "soil" is then laid on the top of the clay mixture in the settling tank and remains there throughout the winter. The amount of "soil" required is usually 20 cub. ft., or one-third of a chaldron, to every thousand bricks. At a later period it is thoroughly mixed with the clay, this latter operation being

called "tempering". In many parts of the country "soiling" is not employed, as the sulphur in the ashes has a strong effect in colouring or discolouring the bricks.

Haulage.—The use of mechanical appliances in getting the clay must depend upon the nature of the material and the depth of the yard, but in any case the construction of a tramway or rails will lessen the cost of moving the clay from one place to another; the employment of these appliances is far cheaper than that of wheelbarrows. In fact, barrows should only be used where wagons cannot be employed. It is not at all necessary for a permanent track to be laid, though this is usually desirable on account of the smoother running. The ordinary track is made with 9 lb. to 16 lb. rails set 20 in. apart. If it is to be portable, one end of each rail should be made with a sleeve into which the other end can be fitted, but for a permanent track the rails are nailed or bolted on to sleepers. The most useful form of a track for moderate sized or small yards is a single track made double in places so as to allow the wagons to pass each other, but where endless haulage is employed it is usually better to have two tracks, as this greatly lessens the risk of accidents.

Direct Haulage is cheapest when effected by means of the rope or chain, but in small yards, or in special cases, horses or locomotives may be necessary. For instance, it not infrequently happens that the clay hole is on one side of the road and the works are on the other, so that rope haulage (unless of the overhead variety) cannot be used. Horses and locomotives are, however, much more costly in relation to the work they do than other systems of haulage, except in those cases where there is an enormous output over a long distance, when it may be found that a locomotive, with a train of wagons, is cheaper than an endless rope or chain.

The simplest system of haulage by rope or chain is obtained by attaching a drum to the engine or other shaft by means of a friction clutch, so that the clutch being put into action the rope or chain is made to coil round the drum and so haul up the wagons. One wagon is hauled up at a time, but with a sufficiently strong rope a number of wagons may be coupled together so as to form a train. This arrangement does not work continuously as does the endless system of haulage, as the wagons must be hauled up and returned to the pit on the same track; but the arrangement is simple in construction, and by choosing wagons of a suitable size can be made to work very satisfactorily

in many yards. If the incline on which the returning wagons travel is at all steep, a brake (usually of the band form) must be employed on the winding drum. On level tracks, or on those which are nearly level, some means must be provided for hauling back the empty wagons, in such cases the ordinary main and tail system, or an endless chain or rope may be used. The main and tail system consists of two drums, one of which works the rope which hauls out the full wagons, and the other, a lighter rope, which pulls back the empty ones. A pulley-block placed at the end of the track farthest from the drums keeps both ropes fairly taut, and one drum unwinds whilst the other winds the rope. The thinner rope or tail rope must usually be about twice the length of the track, and is attached to the free end of the

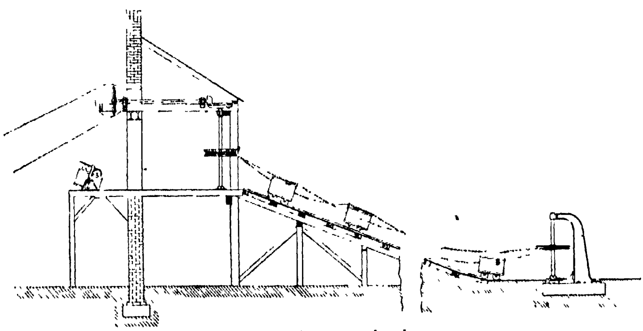

FIG. 5.—Endless rope haulage.

thicker main rope. The wagons are always fastened to the main rope as only one track is used.

In hauling by an endless rope or chain a horizontal pulley is usually employed. This pulley is mounted on a vertical shaft and is driven by gearing from the main shaft (fig. 5). The rope or chain is supported at the farther end by a similar pulley which runs "loose," and the wagons are usually attached by means of simple vertical bars, fitted with a V-shaped opening (fig. 6) at the top. This opening engages with the rope or chain and is sufficient for most inclines. Where necessary, a special clip (fig. 7) may be used to secure a more perfect attachment to the rope. When the number of wagons required is sufficient to support and balance the rope or chain, this system of haulage is the most satisfactory and convenient. It is often necessary to push the wagons by hand for a short distance,

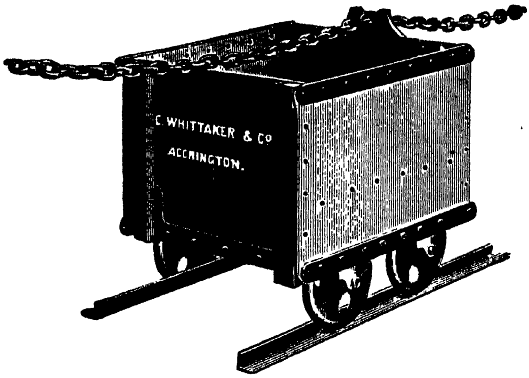

Fig. 6.— Wagon with V-shaped clip.

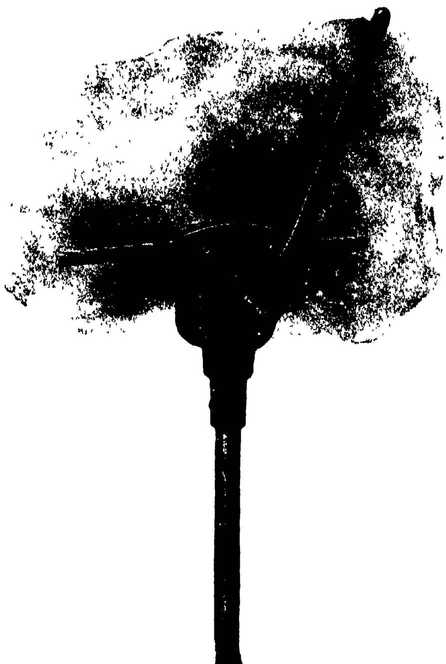

Fig. 7.—Craddock's clip for rope haulage.

especially near the working faces of the clay, but owing to the cost of human labour for this purpose, this part of the work should be made as small as possible, and every advantage given by means of iron plates, turn-tables, or portable rails. The main essential in a tramway system is that a large part of the track must be fixed permanently, though portable switches or joints, as well as permanent ones, often facilitate working.

Turn-tables are essential in some cases. Usually they are permanent structures, but for some purposes a climbing turn-table is better. The climbing turn-table, which is in itself a

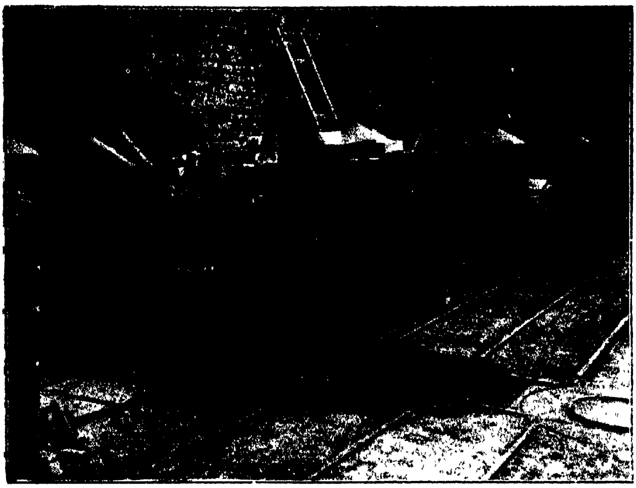

FIG. 8.—Climbing turn-table in use.

special form of large iron plate, can be laid over the rails, and is provided with sloping sides so that the wagons travelling over the track get on to the turn-table (figs. 8 and 9). They may then be turned round in any direction desired, and led on by similar guides to another set of rails. Such a turn-table can be placed at any portion of the track, and so can be used as a temporary switch in places where permanent points are undesirable. It is mainly used to take the wagons in a direction at right angles to the main track when forming a heap for weathering, or in filling and emptying kilns. It has several other uses, and its application at the working face of the clay might usefully be extended to more than is at present the case.

The wagons can be made to hold any quantity from a barrowful to a ton of clay, according to the nature of the material and the system of manufacturing. A number of excellent types of wagons are now on the market. As a rule with endless chain haulage small wagons are preferable, as the load is distributed more evenly, but where horse haulage is used the wagons should hold about a ton of clay. Iron wagons which tip sideways (fig. 10) or endways (fig. 11) are deservedly popular and are made by several well-known firms. Steel wagons of the two shapes illustrated are the best for conveying large quantities of clay at a time. They should be strongly built, without any joints at the corners of the body rim, and should have

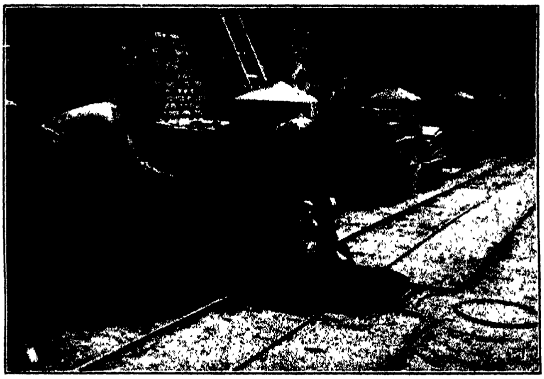

FIG. 9.—Klemp, Schultze & Co.'s portable turn-table (in course of erection).

a strong angle steel framing at inside. The wheels should be specially toughened and provided with ball bearings for easier running. The body should be well balanced so as to tip easily when required, but should be provided with a simple and reliable fastener to keep it from tipping unexpectedly. Where several cars are to be fastened together, swivelled couplings are desirable.

When endless haulage up a steep incline is necessary, small oblong wooden wagons, each holding about 8 cub. ft., are very satisfactory. These are run into a tipping frame and so are emptied. These tipping frames can only be used where the material has to fall to a lower level than the track, whereas

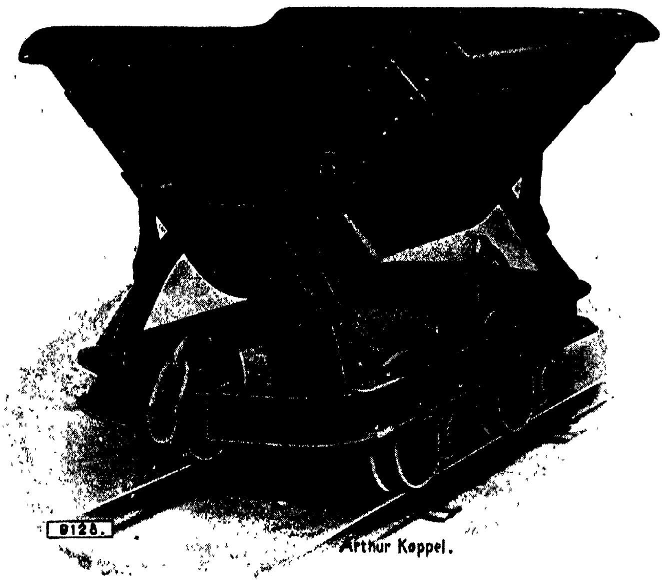

FIG. 10.—Side-tipping wagon.

FIG. 11.—End-tipping wagon.

side-tipping wagons of the type illustrated (fig. 10) can tip on to the level of the track.

The track should be made as straight as possible, as a straight line is always shorter than a curve, and it will often pay to remove irregularities in the ground rather than take the line a further distance round. The slope of the track should not exceed 35 degrees, and it is much better when the inclination is less, as the cost of transporting and the risk of accidents are both reduced on more level tracks. In many yards an artificial staging, or gantry, is used, it being found that this, when made of rough timber, is cheaper than the levelling of the ground for the construction of an earth embankment. The rails used are light and laid 16 to 22 in. apart. Unless used on the gantry they must be laid on sleepers. It is usual to lay the sleepers at right angles to the rails, but brickmakers in America claim that there are advantages to be derived by laying the timbers in the same direction as the rails themselves, and it is certainly far cheaper so to lay them.

The most suitable means for haulage in most brickyards is an endless chain or rope, or a combination of rope and chain. This should not be heavier than is necessary, and a rope ¾ in. diameter is sufficiently large for most purposes. The rope or chain should be supported at intervals by rollers or pulleys, especially if it is near the ground, as nothing wears it out more rapidly than dragging it over a rough surface. The speed with which it travels should not exceed four miles an hour. The wagons are attached to the rope by means of a special clip, but when a chain is used a simple fork projecting above the wagon and engaging one of the links is sufficient. In this case it is usual to arrange the chain so that the wagon is automatically released as soon as it reaches the place where it is desired to stop it. This is done by taking the wagon to a rather greater height than is required, and letting it run down a short incline at the last, the chain being raised well out of the way. With an endless chain the adaptability of wagons in turning sharp curves is very noticeable, especially if at the point flanged rollers are placed to receive the wagon and enable it to leave again in the desired line, the road being inclined in such a way that the fork of the wagon disengages from the chain until the wagon has passed round the curve, when it again comes in contact with the chain and is hauled forward. No special mechanism is necessary, as all that is required is to fix the rollers at the right

height above the wagons, and to see that the slope of the track at the curves is in the right direction. When clips are used they should be provided with an automatic release.

It is often convenient to use two or more endless chains instead of one, as changes in the direction of the track can then be more easily arranged. In such cases a vertical shaft is erected, and on it are fixed two or more rollers or pulleys, one being used for the first endless chain and the others for the second and, if need be, for a third chain.

With all systems of endless chain haulage it is desirable to have some kind of brake to prevent the wagons from running backward on a temporary stopping of the hauling engine, and with several chains on the same axle some brake arrangement is essential. For the former, the simplest form is a collar round the shaft fitted with cogs above and below. A loosely hung bar of steel fits into these, one at a time, and forms a ratchet which compels the pulleys to travel in one direction only. Without some arrangement of this kind the wagons may run back and serious damage be done.

Quite recently aerial ropeways (fig. 12) have been used where the ground is occupied, or where it is irregular or otherwise unsuitable for a tramway. Several firms are now prepared to supply these aerial systems of transport, but the one which has been most successful in connexion with clayworking is that of Adolf Bleichert & Co. In this the bucket is carried by two pulley wheels connected together and running on one rope, whilst a clip on these wheels grips another rope which hauls the bucket to its destination. It is in the peculiar construction of the clip or jaw that the apparatus shown has the advantage over many other arrangements for aerial ropeways, as the Bleichert grip (fig. 13) is formed of two jaws which grip the traction rope. One of the jaws is firmly fixed to the carriage, while the other, constructed as angle-lever, constitutes the counterpiece to the fixed jaw. The weight of the hanger, car, and respective load is borne by the longer arm of the angle-lever. The power of the grip is therefore determined by the proportion of the angle-lever's arms, and as this proportion can be adapted to the maximum gradient of any line, the safety of the apparatus is ensured. The jaws can be made of a sufficient length to avoid damaging the traction-rope. The pressure, with which the rope is gripped by the gripping jaws is produced by the weight of the car and its load, and is increased by means of levers.

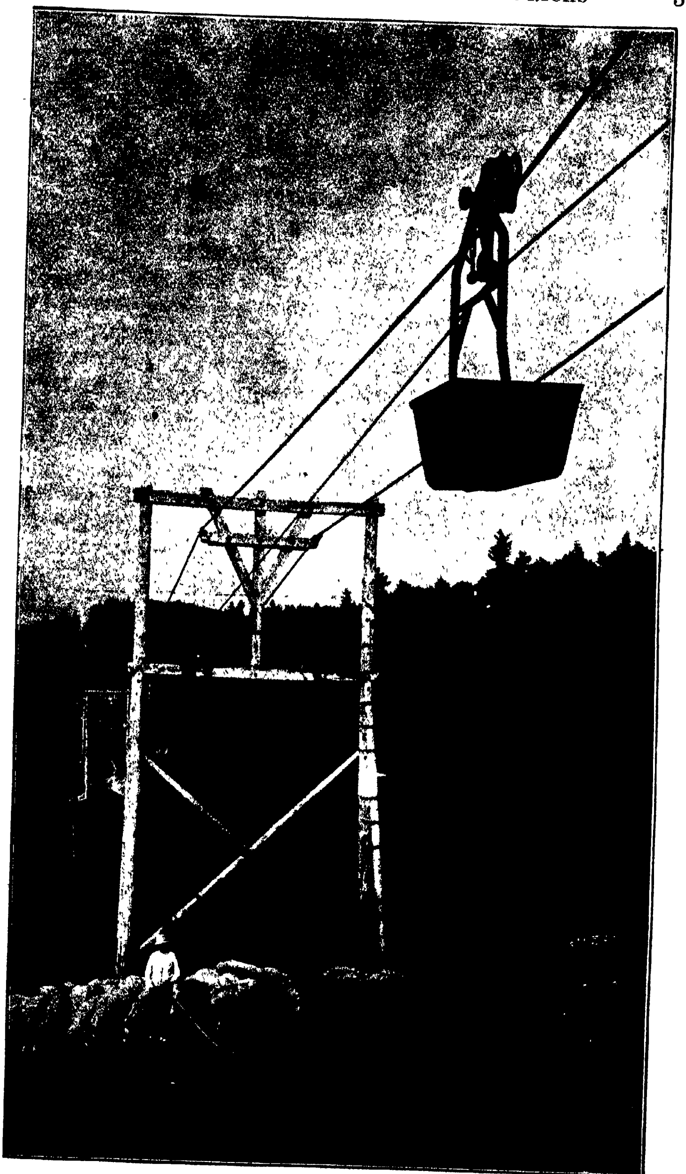

FIG. 12.—Overhead or aerial ropeway.

When barrows are used for moving clay their shape and size is more important than is often supposed, and the distance of the centre of gravity when loaded from the line joining the point of contact with the ground, must be carefully adjusted. If it is over 12 in. the workman will find it difficult to balance the barrow and his output will be diminished.

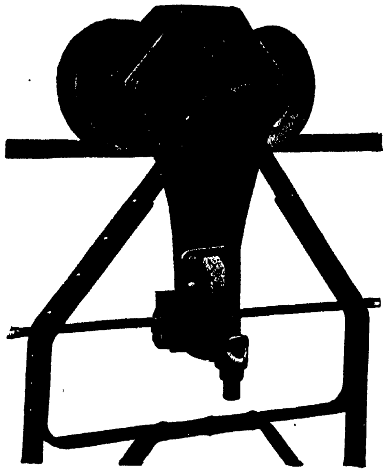

FIG. 13.—Clip and runners for Bleichert conveyer.

The spades used in digging clay should be of medium weight, not too wide, and should have a flat or slightly curved blade, if the clay is pasty (fig. 14). For dry clay a wide shovel with side flanges may be used. In this country the

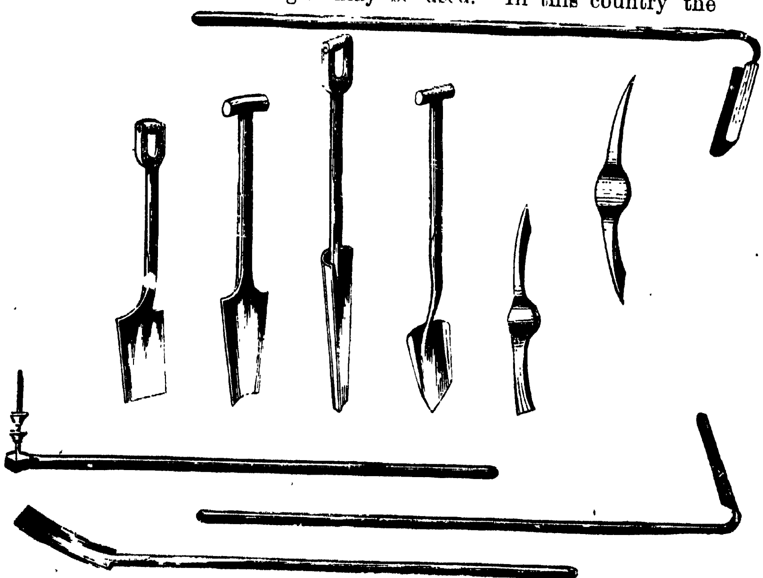

FIG. 14.—Spades, etc., used in clay-digging.

spades have almost straight blades, but in America a strongly sloping blade is considered more satisfactory.

CHAPTER III.

HAND-BRICKMAKING PROCESSES.

Most clays which can be worked up into a suitable plastic paste can be made into bricks by the aid of hand-moulds, but at the present time hand-making is chiefly practised in the South of England for ordinary facing bricks, and in the Midlands and North for the manufacture of fire-bricks, for specially moulded bricks, and terra-cotta. As almost any clay with sufficient plasticity can be moulded into bricks formed by hand, the number of clays of widely differing characteristics described as "brick earth" is very large, and the prospective brickmaker must be careful in his choice of material, for some clays are impossible to use commercially, even when, apart from the cost of manufacture, it is quite possible to make good bricks from them. It by no means follows that because good bricks can be made from a certain clay that they can be produced at a cost which would be commercially satisfactory, and the prospective brickmaker should exercise the greatest caution before embarking on a new enterprise, even when he has seen excellent specimens of articles made from the clay it is proposed to use. Thus, true London clay is very troublesome to those unacquainted with its special nature, as it appears to be highly plastic though in reality it is not so, though it is very sticky. It is very doubtful whether first-class bricks can ever be made from strong London clay, though a commoner brick is made in large quantities. A strong clay, in the absence of an ample supply of mild loam or sand, cannot be made into good bricks, though those of an inferior quality may be produced in some cases. The reason for this is that clay which is very strong shrinks excessively on drying and burning, and so it is almost impossible to prevent cracking to such an extent as to make the bricks composed of it practically useless.

Nodules of all kinds should be avoided in clay to be moulded by hand. They can be removed by washing the clay, but it seldom pays to do this.

Stones, when occurring in a strong clay, are a blessing to the brickmaker, provided that the stony matter is of a siliceous nature (not limestone), but in a very mild clay the presence of stones will reduce the plasticity too much, so that they must be removed before such clay can be used.

Siliceous or sandy stones, when found in strong clay, may be ground up with it, and so produce a mild mixture which will have the proportion of stones and clay which produce a good quality of brick, the colour of which will depend upon the composition of the mixture. When stone-bearing beds occur with clean, mild or sandy clays the stones may be picked out by hand or by some form of mechanical clay-cleaner (page 22), and are frequently valuable as a by-product.

Sand and *Gravel* can only be removed by washing.

The most popular clays for hand-brickmaking are the Oxford, Reading, Bagshot, and Gault beds in the South and the East and the Midland beds, but many surface-clays in different parts of the country are locally considered to be of great value for this purpose.

The Preparation of the Paste for hand-brickmaking is effected as follows: The clay, after any necessary purifications and the addition of any non-plastic material, must be made up into a paste of sufficient softness and plasticity to turn out easily from the mould and to dry and burn without cracking or warping. It is necessary to effect a thorough mixing of the various materials, to ensure their reduction to a sufficiently fine state, and to incorporate the precise amount of water to produce the desired plasticity. The clay may be sufficiently pure to be used direct, with or without the addition of non-plastic materials, such as sand or chalk, or it may have been purified by washing or some other treatment. Turf, top-soil, gravel, or an excessive amount of stone or sand must be removed in the getting of the clay, so far as this is possible, but in certain clays washing cannot be avoided.

Washing is carried out in wash-mills similar to the one described on page 25, the clay being churned up with a sufficient quantity of water to produce a thin slip, or slurry, out of which the stones settle whilst the clay is carried round in the slurry. This is run off to a wash-back, and the clay having settled, the water is run off leaving a stiff paste.

Another useful method of cleaning clay from stones is a mechanical clay-cleaner which consists of a sieve or perforated

screen through which the clay (previously made into a paste) is forced, the stones being left behind (page 24). The disadvantage of these clay-cleaners is that they only separate the larger stones, yet the very small ones, in the case of limestone, may be as detrimental as any; hence, whilst clay-cleaners may be satisfactory when only stones over $\frac{1}{8}$ in. diameter are present, clays containing limestone must be washed if the removal of the small stones or gravel is really necessary.

Clay sufficiently free from objectionable ingredients having been obtained, it is next necessary to reduce it to a state in which it will readily mix with the water required to make it into a uniform plastic paste. If it has been washed it will already be in a pasty condition as it comes from the settling-tanks or wash-backs (page 25), otherwise it must be crushed, unless it is so fine and mild that treading or repeated turning over with a spade will convert it into a state in which it may be taken to the pug-mill.

The crushing or grinding may be effected by a pair of crushing rolls or in a pan-mill with edge runners, the former being generally employed for strong sticky clays and the latter for hard ones. In some cases it is necessary to use several pairs of rolls or a combination of rolls and edge-runners (page 86). Much unnecessary grinding or crushing may be avoided by weathering the clay thoroughly. Indeed, weathering (page 22) should never be omitted when it is likely to benefit the clay, as it effects a disintegration far more complete than is possible with any kind of crushing machine. The oxidizing and other actions which take place in weathering are also important to the brickmaker, and many clays which cannot be used when freshly dug will make excellent bricks and tiles if the clay is exposed to the action of the weather for a short time previous to its being sent to the mills.

Most makers of hand-made bricks declare that hand-moulding cannot be effectively carried out with clays which require much preliminary crushing, and when crushing rolls have to be employed, it is customary to manufacture only machine-made bricks. A notable exception to this is found in the case of fire-brick manufacture in which the hard, rocky clay is first crushed by rollers or pan-mills before being mixed with water and pugged. With most other hand-made bricks the clay is taken direct from the bed or weathering heap and pugged, or it is washed, and the purified clay from the wash-backs is sent to the pug-mill.

For some purposes edge-runner mills give better results than crushing rolls, though they require the clay to be dry and not too sticky if large outputs are desired. The use of edge-runner or pan-mills is described in the chapter on "Stiff-Plastic Brickmaking". These mills are seldom used for bricks made by hand-moulding, though in the manufacture of fire-bricks their manufacture is common and desirable owing to the peculiar nature of fire-clay, which is essentially a rock needing to be ground to a powder before being mixed with water. Clays of a rocky character are usually most conveniently treated by the stiff-plastic system, but when very low in plasticity it may be preferable to use more water (as with fire-clays) and to mould them by hand. They are then best crushed in an edge-runner mill and, after sifting, are mixed with water in a pug-mill until a uniform paste is obtained and a consistency suitable for hand-moulding. Such instances are comparatively rare, so far as ordinary hand-made building bricks are concerned.

After the material has been treated so that no hard lumps remain in it, water must be added so as to convert it into paste. This operation is known as *tempering*, and is best performed a couple of days before the clay is to be pugged. The reason for this is the souring, or putrefaction, which most clays undergo when kept in a moist state, whereby the water is more fully distributed and a more homogeneous paste is the result. The preliminary tempering should be made by mixing some of the clay with water and turning it over with a spade, this operation of watering and turning over being repeated until sufficient water has been added. It is not wise to shirk this part of the process of manufacture, as some makers do who put their clay direct from the crushing plant into the pug-mill.

It is generally wise to allow the clay to soak for some little time before it is turned over by the spade, though in some cases this turning over is unnecessary if the soaking is sufficient. Rocky clays, on the other hand, are scarcely effected by soaking. The use of hot water instead of cold is valuable in the tempering of some clays.

When the clay is taken from wash-backs, the men should be instructed to dig downwards and not take off layers of clay from the top of the deposit. If the various earths of which the bricks are to be made have been previously spread over the surface of the tempering shed, or ground in layers of the required thickness,

cutting the material vertically will ensure the portions taken having the desired composition.

In former times it was customary to continue the spade work, or tempering, of the clay until a plastic paste was produced, this process being aided by the treading of the clay under horses', or men's feet; but this method has, to a large extent, died out in this country (though it is still practised in the manufacture of crucibles for steel making, for retort clay, and for a few other special branches of clay working) as it is found that pugging is more effective and far cheaper for ordinary bricks. In the neighbourhood of London, where ashes are added to the clay, they are mixed in during the process of tempering it by spade labour, previous to the mixture being taken to the pug-mill.

In the manufacture of tiles (where a better price is obtainable in proportion to the amount of clay used) foul clays (i.e. those containing stones) may be soaked for some time, and the paste thus formed is "slung" or cut into thin slices with a wire before being pugged; but this operation does not pay in the case of bricks. When slinging is resorted to, the clay should be passed once through the pug-mill and then cut up into thin slices with a wire, as the time taken in the preparation of the paste is thereby greatly reduced. The object of slinging is to enable the stones in the clay to be readily picked out. A similar purpose is served by the mechanical cleaners already described.

Pugging.—After being mixed with water in the operation of tempering, the clay is in the form of a paste of fairly regular composition. It must be made homogeneous by a further process of mixing; the usual plan being to treat it in a pug-mill, or in a grinding-pan with edge runners and a solid revolving pan. The pug-mill is more commonly used, though in the manufacture of fire-bricks and fire-clay goods the clay paste may be kept in a pan for about twenty minutes with most satisfactory results.

For hand-brickmaking the pug-mill is usually of the vertical type, the tempered clay being thrown in at the top and gradually becoming more uniform in character as it passes through, and is finally discharged at the bottom. The mill with an upright shaft, to which are attached knives passing through its centre, is usually made of wood and resembles a large barrel, but during recent years various alterations in the construction of pug-mills have been made, and many iron cylinders and wooden conical bodies are now in use. The horse-driven mill is slowly, but

surely, giving way to the mechanically driven one, as a horse is unable to give more than a very slight pugging. This is unsatisfactory in the case of unwashed clays, and the use of washed earth is rapidly diminishing on account of the expense of washing and the space occupied by the settling tanks. With washed earth, pugging is scarcely necessary, though it should never be omitted.

The value and efficiency of a pug-mill depends upon its size and upon the arrangement of the knives. If too small, and especially if too short, the mill will not mix the clay sufficiently, and if the knives are incorrect in shape, or are badly arranged, the clay will emerge without being homogeneous. The older forms of pug-mills are singularly inefficient, as the blades are too small to be of much service and the amount of kneading and mixing which occurs is comparatively small. Broader knives, which would act better, require more power than can usually be given by a horse.

A better type of mill is shown in fig. 15, but this is power driven. When constructed according to the suggestions of A. E. Brown, it consists of a conical wooden vessel A mounted on 6 in. square oak cross sills B and between two equally stout uprights CC tied near their upper ends by the cross beams DD and by other strong struts (not shown) which take the thrust of the driving belt or chain. The $2\frac{1}{2}$ in. countershaft F, supported by two plummer blocks *ff*, carries a 5 ft. pulley H (driven direct from a 12 to 18 in. pulley on the engine) and the bevelled pinion K^2 The $2\frac{1}{2}$ in. vertical shaft EE is carried by two plummer blocks *ee* and a foot-step *g*. This shaft is made in two pieces, connected with a sliding coupling G, in order that the upper portion may be turned apart from the lower one when desired, as when a second pug-mill or wash-mill is driven from the chain wheel L, on the same countershaft, the present pug-mill not being required.

Five knives *a*, and a scraper *b*, to force the clay out through the opening C, are provided, the shape of the former being of an American type not well known in this country, but very satisfactory wherever they have been used. The essential feature of these knives is the possession of one unsymmetrical and one flat side, as shown in fig. 16, the shape of the scraper *b* is better shown by fig. 17.

When run at four or five revolutions per minute, a mill of this type, 3 ft. 6 in. diameter at the top tapering to 3 ft. 2 in. at the bottom and 4 ft. 6 in. to the top of the barrel A, will pug sufficient

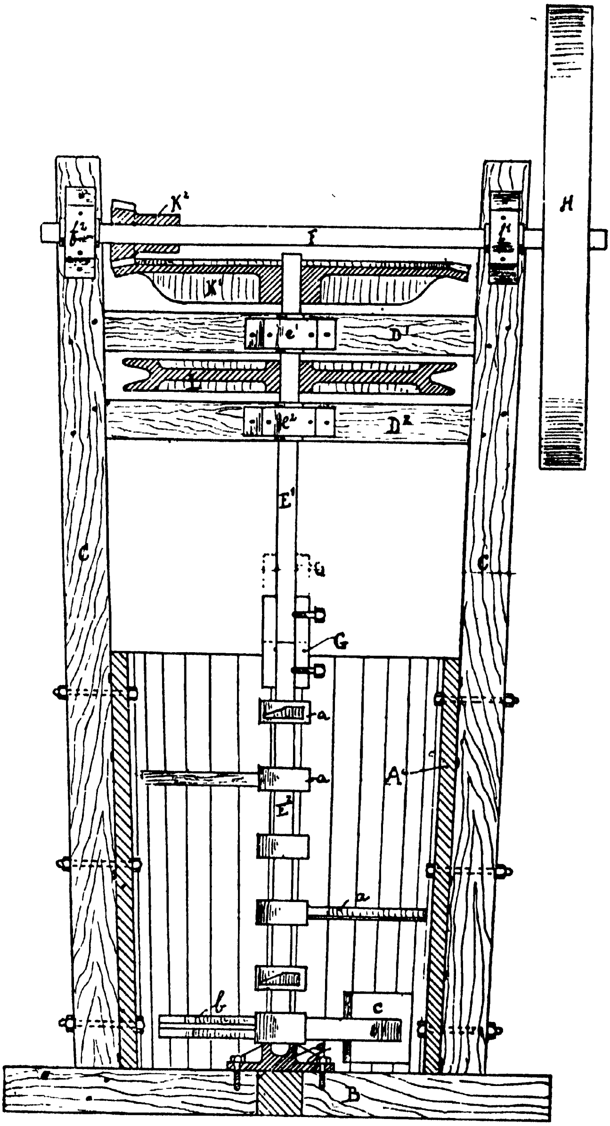

FIG. 15.—Home-made pug-mill.

clay for 6000 bricks per day, although a larger quantity can be turned out if it needs only a light pugging.

Fig. 18 shows a pug-mill of the old horse-driven type, but of

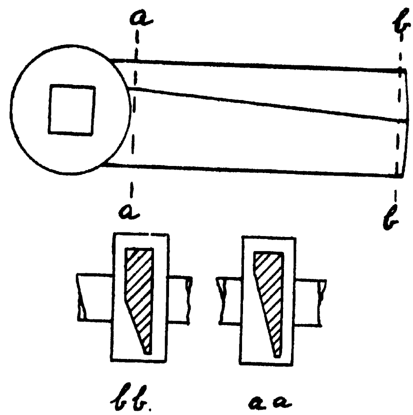

FIG. 16.—Blades of pug-mill (A. E. Brown).

superior construction and capable of preparing sufficient clay for about 5000 bricks per day. The knife is the Archimedean type, preferred by the makers. The knives in this mill do

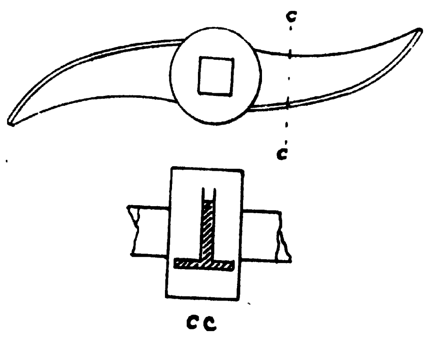

FIG. 17.—Bottom scraper of vertical pug-mill (A. E. Brown).

not merely cut the clay but turn it over in each revolution, so that every part of the clay is submitted to their action, and being furnished with scrapers or cleansing knives, clogging and excessive adhesion to the sides of the mill are prevented, and the whole mass of clay is more thoroughly amalgamated than in the earlier

forms of mill. Like many other mills of this type constructed of iron, this one is deficient both in height and diameter where difficult clays are worked. Unless the circumstances are exceptional, the barrel of a vertical pug-mill for clay for hand-brickmaking should never be less than 3 ft. diameter in any part, nor less then 4 ft. 6 in. high, and only one outlet should be used at a time.

Feeding is facilitated by making the mouth of the barrel somewhat bell-shaped, and the ejectment hole should be fitted with a sliding door in order to regulate the speed at which the clay travels through the mill and to secure its being sufficiently pugged.

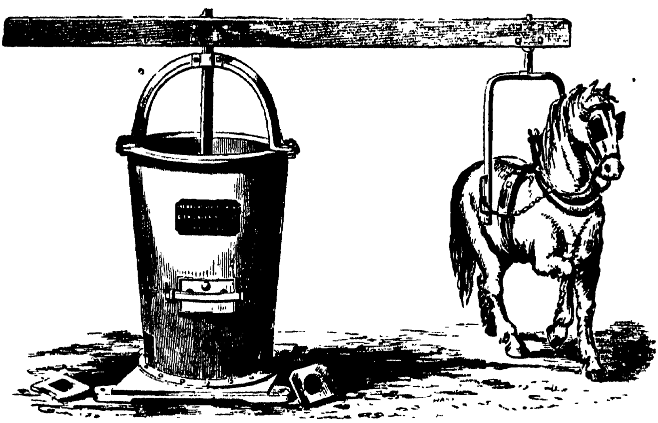

FIG. 18.—Horse-driven pug-mill.

A typical power-driven mill of the all-metal type is shown in fig. 19, but it would be more efficient if made both higher and larger than those usually kept in stock. Mills of this type are supplied by all makers of clay-working machinery and require 2 to 6 h.p. to drive them.

The illustration of the machine in fig. 20 represents a power-driven pug-mill in which the upper part is expanded so as to secure greater mixing power. The machine has two sets of knives, one in the large pan and another in the barrel, and the former are so arranged that at each revolution the clay is taken one step nearer to the centre of the mill. The delivery opening, which is placed tangentially to allow of free delivery, is fitted

with a sliding door actuated with screw and hand wheel, so as to adjust the opening to suit the condition of the clay required, but a simple slide is sufficient for most purposes. Such machines are specially suitable for hard clays which do not mix readily with water, such as shales and fire-clays.

The "Vulcan" mill (fig. 21), made by the Horsham Engineer-

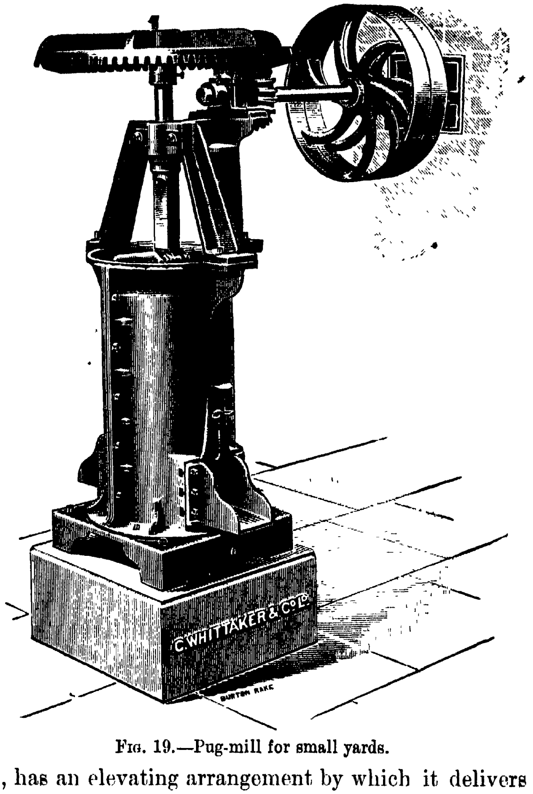

FIG. 19.—Pug-mill for small yards.

ing Co., has an elevating arrangement by which it delivers clay on to the brickmoulder's table and is a useful labour-saving device.

Some brickmakers maintain that horizontal pug-mills are unsatisfactory for hand-made bricks, and that they require more power to drive them. The contention is not well founded, though the effect of gravity in a vertical pug-mill should, theoretically, reduce the amount of power to pass the clay through it. In

some tests made by the author this difference was so small as to be negligible, and it may therefore be left to the brickmaker to suit his own convenience in handling the clay as to whether a vertical or horizontal pug-mill is used. Horizontal pug-mills are described in Chapter IV.

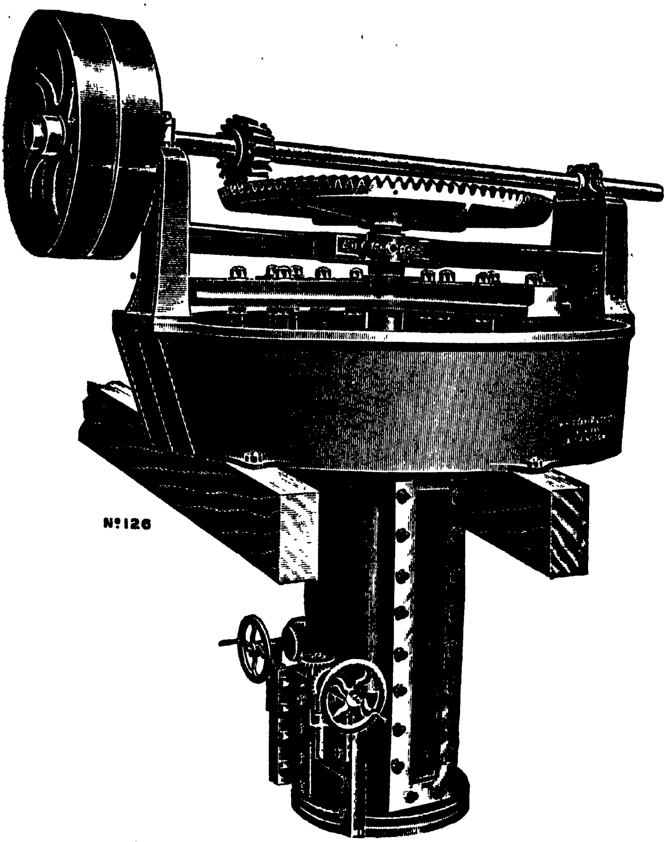

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FIG. 20.—Vertical pug-mill for fire-clay, etc.

The best speed for running a pug-mill will vary with its construction and with the clay used. The makers should be consulted on this matter. An ordinary vertical pug-mill should be worked at a speed of five revolutions of the shaft per minute, but the speed which is really most suitable for a particular clay

can only be ascertained by actual trial. The men engaged in feeding the pug-mill must see that it is kept full of clay, or the latter will be imperfectly mixed.

Moulding.—Two distinct methods of moulding bricks by hand are in use at the present time. In the first, the mould is dipped in water before being filled to prevent the clay adhering to it. This is known as "slop-moulding". In the second method the internal surfaces of the mould are covered with sand, whence the term "sand-moulding" for bricks made by this method.

Considerable differences in dealing with the clay when once the brick has been formed in the mould are also common. Thus in ordinary slop-moulding a boy takes the filled mould

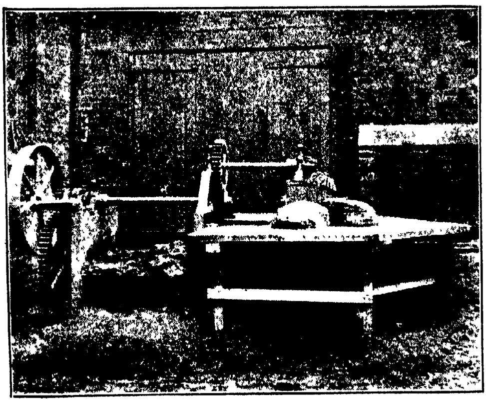

FIG. 21.—Elevating pug-mill.

from the maker's bench to the drying floor and turns out the brick on to the floor, returning to the bench with the empty mould. Meanwhile the maker fills a second mould. In sand-moulding, on the contrary, but one mould is used, and the maker, after filling it, turns out the brick on to a pallet or carrying-board. This distinction does not hold good in all cases, however, as with some clays (notably fire-clays) the bricks are slop-moulded, and then turned on to pallets by the maker. These differences in treatment really depend on the stiffness of the brick in the mould, and the extent to which it can be handled after leaving the latter.

Bricks which have been moulded and turned out on to a pallet are placed on barrows, and a considerable number of them taken

to the hack or drying floor, which may be at a considerable distance from the maker's table, but in some instances drying floors on which the makers move their benches to and fro are employed.

It is convenient, for the sake of clearness, to describe the sand and slop-moulding processes and the subsequent handling of the bricks quite separately, though from the foregoing it will be understood that in some works portions of one process are made to follow those of the other, when the nature of the clay enables this to be done, and time or labour to be saved without detriment to the bricks.

The moulder's table or "stool" is very strongly made, about 6ft. by 3ft. and about 3ft. high, it is provided with various boxes, etc., according to the method of brickmaking adopted, and whilst the shape and size of the table and the fittings differ in various localities the principal arrangements are the same in all.

In Slop-Moulding the table is furnished with a box for sand and another for water, these being so placed that when the moulder is at work the sand-box is at his left hand, the water-tank is in front of him, and the clay ready for use at his right hand, ample room being left for the working of the clay. A larger tank for water stands at the left side of the table.

In making a slop-moulded brick the workman sprinkles some sand on the vacant part of the table immediately in front of himself, takes a lump of clay sufficiently large for his purpose, and kneads it on the sanded table to the shape of a brick. He then takes a mould and dips it into the water-trough so as to wet it thoroughly, at the same time cleaning it from any adhering material, and places it on the table. He next raises the rough shaped clot of clay and dashes it with considerable force into the mould. The next operation consists in compressing the clay so that it may fill the mould completely, and this is done by the workman using his hands, or a small flat board with a vertical handle called a "plane". The superfluous clay is then removed by the workman's thumbs, an even surface being given by finally drawing a straight edged strip of wood (termed a "strike") across the mould. The strike is then thrown back into the smaller water-box. A boy picks up the mould with its contents, and carries it to the dryer floor, where he lays it down, and with a skilful twist of the hand turns out the ready-made brick on to the floor. Meanwhile, the man fills a second mould, and has another brick ready by the time the boy returns to the bench.

Numerous variations of this process are known. Thus, the man may make the boy wash his moulds so that they are wet and ready for use when required. Sand is not used in some cases, the mould being then placed on a moulding-board covered with fustian kept continually wet. Instead of a strike to smooth the face of the brick, a flat polishing tool or plane is sometimes used, both sides of the brick being smoothed in turn. In some yards, as already mentioned, the bricks are sufficiently stiff to bear more handling, and are therefore turned out on to pallets as described in hand-moulding. It will be seen that the distance the carrying-off boy has to travel must not be greater than will allow him time to return to the table by the time the moulder has a fresh brick ready. On this account, the men who work by the slop-method are compelled to be close to the drying-shed, and usually work in it. The boy starts setting down the bricks in a series of straight lines extending from the wall of the shed to the table, and as soon as a considerable portion of the floor is filled with bricks the table is moved to a fresh position. The object of this is to reduce the distance travelled by the boy as much as possible, without unduly hindering the moulder by too frequent movings of the table.

The bricks on the drying floor are often covered with a thin sprinkling of sand to prevent them cracking, and may afterwards be taken to the kiln or to a hack-ground where they are stacked up for further drying.

The output of a man working by the slop-method with the necessary attendance is seldom more than 10,000 bricks per week, and 1500 bricks per table is reckoned a good day's work. This is much less than the output where sand-moulded bricks are made. Under specially good conditions, and with a clay which can be worked fairly stiffly, a daily output of 2000 slop-moulded bricks can be reached, but is only maintained with difficulty. In Central Ireland the author has seen two men and two boys producing 1000 bricks per hour for five hours at a stretch. They were extremely rough, and the clots prepared by one man were simply thrown into the mould and roughly "thumbed off" by another, the mould being kept in a tub of water when not being filled.

In making *sand-moulded* bricks a different mode of procedure is employed. In this case the moulder's table is provided with a deep rim at each end and partly along one side to keep the sand in place, a small box containing water for holding the

strike, and a "stock-board" or "bed" on to which the mould fits close to the table, and often fastened to it is a projecting beam, 3ft. to 6ft. long, on which are two thin iron rods fastened parallel to each other, and which serve as rails along which the pallet boards may slide. This appliance is termed a "page". The moulder stands facing the table with the "page" at his left hand, and on his right is an attendant (often a woman) known as the "clot-moulder," the sand for the use of these two workers being placed at the opposite ends of the table.

In order to make bricks by this process, the clot-moulder sprinkles part of the table with sand, and, on the portion thus prepared, kneads up a lump of clay of the correct size into a rough brick and places it ready for the moulder. This man, having sprinkled the stock-board or bed with sand, plunges the mould into the sand-heap and covers its inside surfaces with a thin coating of sand and places the mould on the bed. He then takes the clot prepared for him, dashes it forcibly into the mould, and presses the clay with his fingers so as to completely fill the mould. This operation is known as "walk-flatting" and requires considerable skill. If the clot is too small sand-folds will appear on the face of the brick, and if too large it will not enter the mould properly.

When the mould is filled, a sufficient thickness of clay should project from the top of it to provide a clean, raw base for the next brick, and care must be taken that the moulder takes this off with his thumbs or with a wire and lays it on the freshly sanded table with the cut face downwards. Otherwise, sand-folds are inevitable when the clot-moulder puts a fresh piece of clay on to this and proceeds to shape one clot from both.

The excess of clay having been removed by "thumbing" or with a wire, the surface of the brick in the mould is smoothed by drawing a straight edged strip of wood (termed a "strike") across it in such a manner that the arris of the strike removes any excess of clay. The flat side of the strike must not be used, and to obtain a good finish the strike must be kept very wet. The mould is next lifted from the stock-board, placed against an empty pallet, and, by a dexterous twist, the brick is turned out on to the latter and left on it on the page. The mould is freed from any adhering material, again sanded, and is ready for use. If the sand will not adhere properly to the mould the latter is wetted occasionally.

The brick with its pallet is taken from the page by a boy and

placed on an off-bearing barrow, and when the latter is full, sand is sprinkled over the bricks and they are carefully wheeled away to the hack-ground or dryer, where they are set on edge, in hacks eight or nine bricks high with the aid of a second pallet placed on top of the brick, so as to enable it to be carried and turned sideways. Very thick bricks should only be set five or six bricks high.

The construction of the off-bearing barrow is a matter requiring some attention. Too many of those in use are badly balanced (making the labour of wheeling unnecessarily great), or they are built too low for the most convenient work. A well-designed off-bearing barrow must be capable of travelling over rough ground without the bricks on it being damaged, and yet the arrangement of the springs must be simple and not likely to get out of order. Spiral springs and those of the bow type are not usually satisfactory, and a much better pattern is that supplied by W. Bracknell. In this the spring is a plain strip of steel with a double curve, and is so placed that the axle of the wheel is at the strongest and most rigid part of the barrow, whilst the bricks are supported by a spring of ample size and power. In most barrows the springs are placed in such a manner that strength is lost, and the "life" of such barrows is consequently short.

With three barrows—one of which is always being loaded—two men to wheel and hack, a boy and a clot-moulder, a brickmaker can turn out 4000 to 5000 bricks per day if he is kept well supplied with clay, and a weekly output of 30,000 bricks is not infrequent. Where best quality facing bricks are required, a lesser output must be expected on account of the greater care required.

Although the work looks easy, moulding bricks by hand really needs highly skilled labour, and it has with some truth been said that "a good moulder is born and not made". Much may be done, however, by patient insistence and careful watching on the part of the owner of the works.

Until lately, the moulds used for hand-made bricks were made of wood, but these have been largely superseded by brass, or as they are technically called "copper" moulds, or by those lined with or made of iron or steel. Wooden moulds are only suitable for sandy clays and it is almost essential that they be wetted during use (as in slop-moulding). Iron and steel lined moulds can be used with sand and without water, and brass

moulds need neither sand nor water, but are too costly and insufficiently durable for ordinary use. Zinc-lined moulds are much used for bricks of special shape.

Brick moulds must be sufficiently rigid to preserve their shape perfectly in use, in spite of the force applied in filling the moulds, and yet they must not be so stoutly made as to be inconveniently heavy. On this account wood is always used for the major portion of the mould, a metal lining being inserted to facilitate the turning out of the brick. Teak and oak are the best woods for this purpose; others swell and shrink too much to be satisfactory.

A typical mould has a lining overlapping the woodwork on each side, and as this wears away the moulds must be relined or replaced with new ones. This mould has no bottom, the lower face of the brick being formed by the table on which the mould is laid.

Another mould is of the type chiefly used in the London district. It has a separate bottom or "stock-board" which is fastened to the table by a peg at each corner. This stock-board is made of wood with an iron plate, a special centre-piece (termed the "kik") being used to make a frog or hollow centre-piece in the brick. The mould itself is a rectangular frame of iron, or wood faced with steel, which fits on to the stock-board and rests on the four corner pins when in use.

The use of four set-screws in place of these corner pins, as suggested in Barton & Co.'s mould, fig. 22, is a great improvement. In this case the plate B and the stock-bed A are fastened firmly to the table E by means of the bolt C, and the thickness of the brick can be regulated to the greatest nicety by altering the set screws A until a sufficient space exists between the top of the plate B and of the mould D.

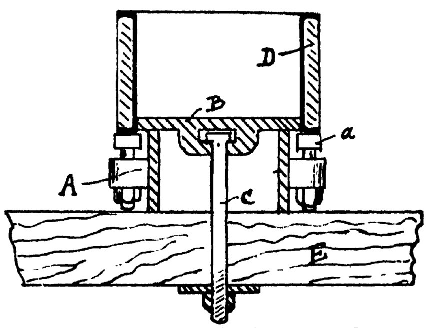

FIG. 22.—Improved hand-brick mould.

Box-moulds which have a fixed bottom piece attached to the

sides, should only be used for fancy bricks. When plain bricks are being made they are little or no better than when the ordinary mould is used.

Drying.—By whichever method of hand-moulding bricks are made, they must be dried before they can be placed in the kiln. The amount of water in the bricks will determine, to some extent, the best method for removing it, for if the bricks are very soft they must usually be laid out on a drying floor until sufficiently stiff to bear stacking. If, on the other hand, sand-faced bricks are made, they can usually be taken to the hacks and stacked immediately.

In small yards where hand-made bricks are produced, artificial dryers are seldom worth installing, and a hack-ground will meet most requirements. If bricks are to be made during the winter, however, a drying-shed heated by steam or a series of fires will be necessary.

The ordinary hack-ground consists of a large field. The usual allowance is one acre of land for each million bricks produced in the season, as level as possible, on which the bricks are laid in narrow rows about 50 to 80 yds. in length, and 9 ft. to 12 ft. from centre to centre of each hack or row.

The direction in which the hacks run is also important; it should be north to south or north-east to south-west, so that both sides of the hacks should receive an equal amount of sun, and yet neither side be exposed to the direct rays of the sun at mid-day. Small trenches should be dug running in the same direction as the hacks, and 3 in. land drain-pipes laid under the hacks at intervals of every ten yards to secure ample drainage. Though not often done, it is a wise practice to use the earth dug out of the trenches to form small embankments on which to place the bricks. This simple arrangement will prevent a considerable number of bricks from being spoiled by wet weather.

In very damp situations the bricks should not be set direct on to the ground but on thin planks, or preferably on hollow pipes of rectangular section 12 × $4\frac{1}{2}$ × $2\frac{1}{2}$ in. (fig. 23) placed side by side. These "tiles" can be made quite cheaply in an ordinary pipe machine. They last several years, and the air passing through them prevents the green bricks from drawing moisture from the ground when such tiles are used.

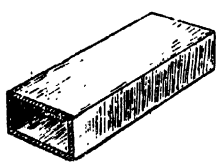

FIG. 23.—Hack tile.

Each row, or hack, consists of two blades of bricks with a space of about 8 in. between each. The bricks are set on edge about 5 to 8 in. apart, the bricks in each row covering the spaces between those in the row below it, and the whole hack being about 36 in. high. In setting the bricks, each row must be laid along the whole length of the hack before commencing another, as, if set to the full height at once, the lower bricks would collapse.

When hacking bricks, the men should always lay a setting board (a kind of pallet board but sometimes a little thicker) on the brick, and lift the latter between the two boards and so carry and place it on the hack. Handling bricks with bare hands invariably defaces them, and is no quicker than when pallet boards are used.

To protect the bricks from rain, the hacks are covered with small, roof-like structures made of light boards, though in some cases straw is laid on the bricks. For many reasons straw is not satisfactory, and wooden covers, either of the portable kind shown or a permanent wood roofing over the hacks, should be used. For a clay of unusual delicacy it may be necessary to cover the bricks with straw to prevent too rapid evaporation of the moisture in them. Loose wooden covers, such as that in fig. 26, cost about 1s. each. They should be made of 12 planks, 6 in. by ⅜ in., set at such an angle as to measure 42 to 48 in. across the bottom of the gable.

For protecting the sides of the hacks from too rapid drying, draughts, or rain, sacks, matting, or loose boards are used, the last named being the best if properly constructed, though matting has the advantage of permitting a freer circulation of air. If boards are used they should be fastened together to form "loos," 6 ft. long by 2 ft. 6 in. wide, with the strengthening ribs lengthened to act as legs as shown in fig. 24.

For better qualities of bricks, sheds containing racks must be used, or an artificial dryer installed. A good type of plain shed for this purpose is that shown in fig. 25. According to A. E. Brown, such a shed 85 ft. × 30 ft. will dry 100,000 bricks per season, and leave ample room for the moulder and engine, and a clear 20 ft. × 30 ft. space for stacking dried bricks. The roof is of galvanized iron, with ½ in. match-board lining carried on posts 10 ft. apart. The sides are fitted with a double row of shutters, or they may be built of perforated bricks. The racks are 15 ft. long and 2 ft. wide and about nine shelves high, with gangways 3 ft. wide between them.

In some parts of the country, the bricks as they lie on the floor of the drying-shed, or during the process of hacking, are tapped gently with a clapper, which is a piece of wood rather larger than a brick with a handle in the centre. This clapping is intended to remove defects in the shape of the brick due to carelessness or accidents in the setting down. When polished bricks are required they must be obtained with a wedge-shaped tool termed a dresser, this operation being carried out on a bench or table about 4 ft. long by 2 ft. high, covered with a plate of iron or steel so as to give them an even surface. This toughens the bricks, corrects any accidental warping, and leaves edges on the bricks very sharp; but pressing has now replaced dressing on acount of the lower cost.

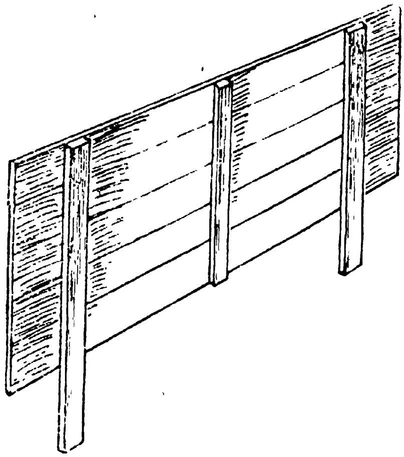

FIG. 24.—LOO.

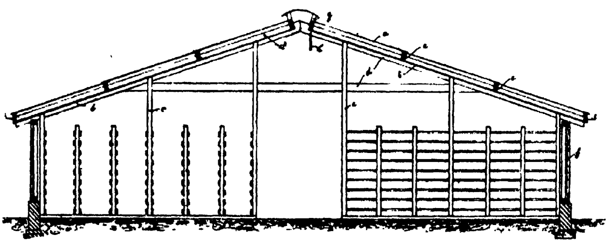

FIG. 25.—Drying shed.

An end view of a hack is shown in fig. 26, which is drawn to scale. The height of the hack depends on the stiffness of the bricks.

A different type of hack, which has been favourably received in Germany, is shown in fig. 27. It is more expensive to con-

struct than the temporary ones just described, and the wood has been preserved with creosote before use. As the sketch is drawn to scale, and the chief dimensions are shown, no further description is necessary, especially as in this country a dryer heated by steam or fuel is cheaper in the long run than is a permanently erected set of hacks of the type shown.

Skintling.—When the bricks in a hack are half dry and are stiff enough to be handled, they are "skintled" or set farther apart and diagonally to let air pass more freely through them. As the skintled bricks occupy more space than those set apart

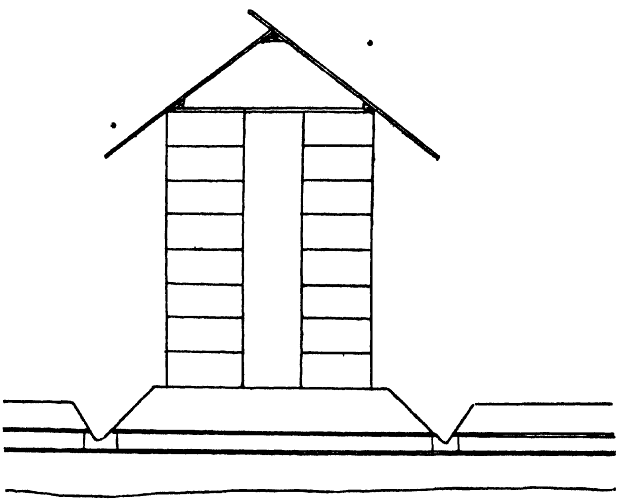

FIG. 26.—End view of hack.

in the ordinary manner, the hack must be built higher so as to still accommodate the original number of bricks.

Pressing.—When hand-made bricks are to be pressed, it is necessary to set them less than eight bricks high, and to take them to the press before they have become too dry. To prevent excessive drying of the ends, the bricks may be "skintled". Bricks which are to be pressed require very careful watching, particularly in warm weather, and an ample supply of matting is necessary to prevent them from becoming too hard. The press most suitable for hand-made bricks is one which can be wheeled alongside the bricks in the hacks, and must therefore

be of the portable, hand-power type. A number of such presses are on the market and are very similar to each other. Fig. 28 shows a press of this type made by the Brightside Foundry and Engineering Co., Ltd., which, in spite of minor defects, can be recommended on account of its portability and low cost.

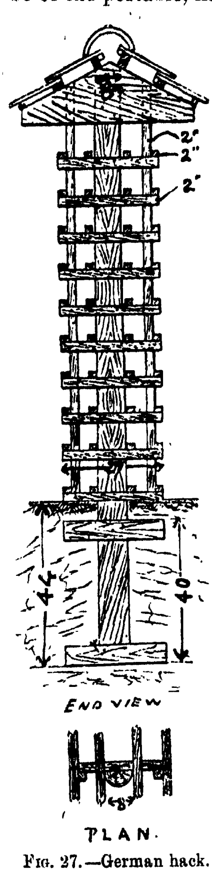

FIG. 27.—German hack.

A single motion of the lever closes the box and presses the brick, and the reverse motion of the lever opens the box and raises the brick. The cover is thrown back, leaving the top of the mould quite free for the removal of the brick and the insertion of a fresh one. The bottom piston is fitted with a groove all round, in which the makers suggest coarse wool may be put for carrying the lubricating medium. This wool may be soaked with paraffin and a small quantity of engine oil, and as the mould moves up and down this lubricates the sides. If not lubricated, the clay would stick to the sides of the mould, and a clean brick would not be turned out. If brick-press oil is used, the bricks are liable to scum in drying. This machine when operated by one man and a boy will press 5000 bricks per day, or one man working alone can press 2000 bricks and set them back again on the hacks to complete the drying. The press will need a considerable amount of cleaning when sand-faced bricks are pressed, and care is needed to see that the mould is kept really clean.

Fig. 29 shows a similar press made by John Whitehead & Co., Ltd., in which the weight-lever is adjusted so that the pressure given can be adapted to bricks of varying thickness.

The chief disadvantages of hack-drying are its extreme slowness (three to six weeks being required), the loss through bricks damaged by bad weather, and the very considerable expenditure necessary for repairs. The wheeling to and fro from the hacks, skintling, attending to matting, etc., are also expensive,

and it may be taken as a general rule that from the moulds to the kilns bricks cost at least 3s. 3d. per thousand for drying.

Kilns.—Hand-made bricks were at one time burned exclusively in clamps, but in more recent years permanent kilns have been used. Clamps are practically the only form of "kiln" used for stock bricks in Kent, Essex, and parts of Sussex, as clamp-burned bricks are preferred by architects and builders using bricks from these countries.

The choice of a kiln is largely determined by the quality of bricks it is desired to produce and by the financial status of the

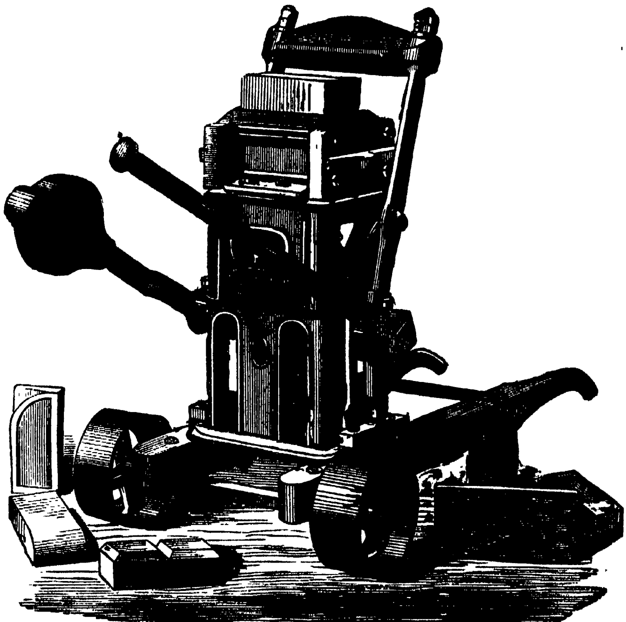

FIG. 28.—Press for hand-made bricks.

brickmaker. If hand-made bricks are made in relatively small quantities it is seldom desirable to burn them in continuous kilns notwithstanding the low fuel consumption of this type of kiln, and clamps or single up- or down-draught kilns are, therefore, preferable.

Opinions differ greatly as to the best shape for a kiln for hand-made bricks, but the author prefers a rectangular to a circular shape, as he has found it both easier to build and set.

For outputs of 1,000,000 and upward bricks a year a continuous or semi-continuous kiln may be used with advantage.

Various types of permanent kilns—both single and continuous—are described in Chapter VIII, as they are applicable to all kinds of building bricks. Clamp kilns may, however, be more conveniently considered here as they have a special connexion with hand-made goods, being considered essential for the manufacture of London stock bricks in which fuel is mixed with the clay previous to its being made into bricks. The great popularity of the clamp for temporary purposes is fully justified where the appearance of the bricks is of less importance than their strength, and it is wise for a firm starting a new yard to commence with a clamp in order that they may thereby obtain bricks for erecting their buildings and permanent kilns.

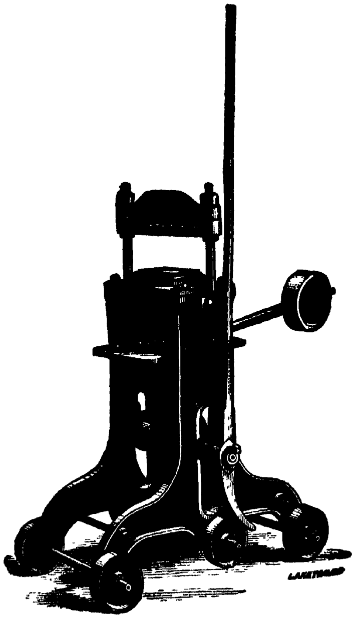

FIG. 29.—Adjustable lever press.

A *clamp* is formed by setting bricks together in a special manner, so that they may be efficiently baked without the necessity of putting them in a permanent kiln. The term "clamp" is used in two senses—one meaning merely a temporary kiln and the other a special arrangement of bricks which it is necessary to use when the clay is mixed with fuel before being shaped. The latter meaning is the one used in the yards where London stock bricks are made. The chief characteristic of this latter kind of clamp is that the bricks become "fireballs" when the fuel contained in them gets sufficiently hot to burn, and the firing once properly started, no additional fuel is required.

Many differences in detail in the construction of clamps are found in the various districts where they are employed, and as

great skill is required both in the setting and burning of bricks by this method, only men really used to the work should be employed. The following description by the late Edward Dobson is typical of the best practice around London:—

A clamp consists of a number of walls or necks three bricks thick, about sixty bricks long, and thirty-four to thirty-six bricks high, in an inclined position on each side of an upright or double battering wall in the centre of the clamp, the upright being of the same length and height as the necks, but diminishing from six bricks thick at bottom to three bricks thick at top. The sides and top of the clamp are cased with burnt brick.

The ground is first carefully drained and levelled and made perfectly firm and hard. The exact position of the clamp having been fixed, the ground is formed with a flat invert, whose chord is equal to the width of the intended clamp. The object of this is to give a "lift" to each side of the clamp, which prevents the bricks from falling outwards as the breeze becomes consumed. The ground being prepared, the upright is commenced. But, previous to building, the clamp barrow-roads, or tramways of sheet iron, are laid down between the hacks and extended to the clamp ground, to give an easy motion to the barrows used in clamping; the bricks being piled on each other several courses high on these barrows, and the wheeling carried on with considerable velocity, they are apt to upset.

The upright is commenced by building two 9 in. battering walls, about 45 ft. apart, of burnt bricks laid on edge which are termed close bolts, the length of each wall being equal to the thickness of the upright which at the bottom is six bricks thick, or about 4 ft. 6 in. (their height is sixteen courses or about 6 ft.). Between these bolts a line is stretched, by which the upright is built true. The ground between the bolts is paved with burnt bricks laid on edge, to exclude the moisture of the ground. Upon this paving are laid two courses of burnt bricks with spaces between them, termed skintles. In the bottom course of skintles the bricks are laid diagonally about 2 in. apart. The second course consists of burnt bricks on edge, laid across the lower one, in lines parallel to the ends of the clamp and also 2 in. apart. In laying these two courses of skintles, a live hole is left about 7 in. wide, the whole length of the upright; and on the completion of the second course the live hole is filled up with faggots, and the whole surface covered over with breeze, which is swept or scraped into the spaces left between the bricks.

On this surface is placed the first course of raw bricks, laid on edge and quite close, beginning over the live hole. Over this first course of raw bricks is laid a stratum of breeze, 7 in. thick, the depth being increased at the ends of the uprights to 9 or 10 in. by inserting three or four bricks on edge among the breeze. The object of this is to give an extra lift to the ends. The first course of bricks, it should be observed, is laid "all headers". Over the first layer of breeze is laid a second course of raw bricks on edge, "all stretchers". This is covered with 4 in. of breeze, and at each end are inserted two or three bricks to increase the lift still more, but this time they are laid flat not edgeways. Upon the 4 in. layer of breeze is laid a heading course of raw bricks laid close, and on this 2 in. of breeze, without any extra lift at the end. To this succeed stretching and heading courses of raw bricks on edge, laid close up to the top of the clamp, a layer of breeze not more than ⅝ in. thick being placed on the top of each course, except on the top course which has 3 in. of breeze. The top of the upright is finished by a close bolt of burnt bricks. The upright is built with an equal batter on each side, its width diminishing from six bricks lengthways at the base to three bricks lengthways at the top. In order that the upright should be perfectly firm, it is necessary that the bricks should be well tied in at the angles; and, in order to obtain the proper width, the bricks are placed in a variety of positions, so that no very regular bond is preserved, as it is of more consequence to keep the batter uniform.

The close bolts first commenced, and which form the outer casing of the clamp, are not built close to the raw bricks, there being a small space left between the clamp and the close bolting, which is filled up with breeze. The close bolts, however, are built with a greater batter than the ends of the upright, so that they just touch the latter at the sixteenth course, above which the clamp is built without any external casing. When, however, the upright is "topped," and whilst the top close bolting is going on, the casing is continued up to the top of the clamp. This upper casing is called the "bestowing," and consists of five or six courses of burnt brick laid flat, forming a casing 4½ in., or half a brick thick; and above the sixth course the bricks are laid on edge, forming a still thinner casing only 3 in. thick. When the weather is bad, and during the latter part of the brickmaking season, a little extra bestowing is given beyond what is here described. The great art in clamping consists in the proper

construction of the upright, as the stability of the clamp depends entirely upon it.

The remainder of the clamp consists of a number of necks or walls leaning against the upright. They are built in precisely the same way as the upright, as regards invert, close bolts, paving, skintling, breeze, and end lifts. But there is this essential difference, viz. that they are parallel walls, built in alternate courses, of headers and stretchers laid on edge, each heading course in one neck being opposite to a stretching course in the next neck, and vice versa. The thickness of each neck is made up of three bricks lengthways in the heading courses. The necks are closely bolted at the top, and "bestowed" in the same manner as the upright. When the last necks have been built, the ends of the clamp are close bolted, and "bestowed" in the same way as the sides, and this operation completes the clamp.

The number of necks on each side of the upright may be extended to eight or nine, without an additional live hole; but if this limit be exceeded, additional live holes are required. According to the judgment of the brickmaker or the demand for bricks, the live holes are placed seven, eight, or nine necks apart. It is not necessary that the additional live holes should pass under the centres of the necks, and it is more convenient to form each live hole so that the face of the last built neck shall form one of its sides.

The erection of a good clamp is a difficult operation which can only be learned by experience.

Firing a Clamp.—The fuel used in burning the laid bricks consists of cinders (breeze, as before described) which are distributed in layers between the courses of bricks, the strata of breeze being thickest at the bottom. To light the clamp, live holes or flues 7 in. wide and 9 in. high are left in the centre of the upright at every seventh or neck. These live holes extend through the whole thickness of the clamp and are filled with fraggots which, being lighted from the outside, soon ignite the adjacent breeze.

The fire is kept up for about a day, until the faggots in the live hole are thoroughly ignited, and as soon as this is found to be the case, the fire is removed, and the mouth of the live hole stopped with bricks, and plastered over with clay or mortar. In firing a large clamp with many live holes, it should be begun at one end only, the live holes being fired in succession one after

another. The clamp burns until the whole of the breeze is consumed, which takes from three to six weeks.

The bricks at the outside of the clamp are usually underburned; they are called "burnovers," and are laid aside for reburning in the next clamp that may be built. The bricks near the live holes are generally partially melted and run together in masses called "clinkers" or "burrs". The bricks which are not fully burned are called "place bricks" and are sold at a low price, being unfit for outside work or situations where they will be subjected to much pressure. The clinkers are sold by the cart-load for rock-work in gardens and similar purposes.

The number of underburned bricks from the edges of the clamp ("burnovers") may be greatly reduced by feeding a little coal into them during the burning of the clamp, or to a less extent by partially covering the top of the clamp with asbestos sheets so as to throw the draught more to the sides. The best way is to place a row of screenings or small hard coal along each side of the clamp, at the top, forming it into a ridge about 12 to 18 in. high. The bricks at the outside are set a little more openly than usual, and a row of skintled bricks forms the outer row. When the bricks nearer the centre of the kiln are well under fire, the burner goes on to the top of the kiln, and with a broad-ended poker pushes the bricks under the coal ridge aside and allows a little coal to fall among them. This operation is repeated every forty or sixty minutes, care being taken not to drop sufficient coal down to choke up the flues and not to add a fresh portion until the previous one is nearly all burned away. This method may also be used with great success in continuous kilns of the archless type.

The quantity of breeze required varies much with the quantity of earth. The usual proportions for every 100,000 bricks are about 12 tons of the sifted ashes, mixed with the brick earth, and about 4 tons of the cinders, or breeze, to light the clamp.

The quantity of fuel to the live holes it is difficult to calculate; about 2s. may be taken as the average cost of coals and wood for every 100,000 bricks. If the proportion of breeze be too small, the bricks will be underburned, and will be tender and of a pale colour. If too much fuel be used, there is a danger of the bricks fusing and running into a blackish slag.

Another system of clamping is to begin at one end and to follow with the necks in one direction only. This is done when the clamp ground is partly occupied by the hacks, so as to render

it impossible to commence at the centre. When this system is adopted, the clamping begins with the erection of an end wall, termed the upright and outside, which is made to batter very considerably on the outside, but of which the inside face is vertical. As regards dimensions and modes of building, the outside and upright are built in the same way as the ordinary upright, but it has, of course, no live hole under it, the first live hole being provided in the centre of the second or third neck. In this style of clamping the necks are all upright. The live holes are placed at every eighth or ninth neck, as in the usual system.

The practice with regard to the paving of burned bricks is very variable. Some clampers omit it altogether, others pave only when clamping for the first time on a new ground. When burned bricks run short, as in building the first clamp on a new ground, the second course is laid with raw bricks. This is, however, a very objectionable practice.

The live holes are sometimes close bolted at the sides to prevent the breeze from the skintles falling into them. This is not often done, and its utility is questionable.

Some clampers put the 7 in. stratum of breeze on the top of the skintles instead of placing it over the first course of raw bricks; very frequently the breeze is dispensed with after the 2 in. stratum, with the exception of the top layer. All clampers, however, agree as to the necessity of having the 7 in., 4 in., and 2 in. layers. Where breeze (cinders or coke) cannot be obtained, small coal or anthracite (culm) may be employed, and in Ireland peat or turf is used, though with indifferent success.

CHAPTER IV.

PLASTIC MOULDING BY MACHINERY.

In order to overcome the difficulty of obtaining skilled moulders —a difficulty which has greatly increased within the last fifteen years—various machines have been placed on the market which, it is claimed, do away with the skill ordinarily required in moulding by hand. These machines must not be confused with others in which no resemblance to hand-moulding is attempted, though this latter class of machine has increased enormously in popularity in recent years on account of the large outputs possible.

Machines which seek to replace the skilled labour of the moulder are usually designed so as to force the clay into box moulds, similar to those used in hand work, from a box or tank, by means of either a pug-mill or special knives. Their great drawback has been the ineffective filling of the moulds and the inclusion of air within the bricks, but in the machines described below, these difficulties have been sufficiently overcome to make the manufacture of bricks by them satisfactory and far simpler from the managerial point of view, at any rate as far as certain mild clays are concerned.

In many districts the wire-cut process of brickmaking is displacing the soft mud machines, though where a facing of sand on the bricks is demanded, the latter machines, or hand labour, must be used.

It is essential that all machines used for making sand-faced bricks must be provided with some safety release which comes into operation when stones or other causes of excessive pressure [illegible]cur. Otherwise the machine will be damaged, and however [illegible]ble a machine may appear to be in other respects, the [illegible]ome form of effective relief escapement should be [illegible]cient to condemn it.

[illegible]und, and it is necessary to decide in which [illegible]me regard must be paid to the probable [illegible] goods required. Where sand-

faced bricks are in great demand it will probably be necessary to use a machine of the "Monarch" or "Bawden" type, in which the production of hand-made and sand-faced bricks is skilfully imitated. Where a dryer can be employed, and the sand-facing of bricks is not considered necessary, a wire-cutting table attached to a pug-mill press will be cheaper for a moderately large output, especially as bricks with a wonderful accuracy of form and size can be obtained by means of a re-press. Hand-made bricks can also be re-pressed if desired, though in this case a portable press is invariably used. The disadvantage of pressing sand-faced bricks is that a large amount of cleaning of the press is necessary, but a strong lad should be able to press, unaided, and re-place on the hack for final drying, at least 1250 bricks per day and 1500 should be considered a reasonable output. It is better in pressing sand-faced bricks to work in this way instead of wheeling the bricks to a permanent press and back again to be dried.

Fig. 30 is an illustration of the "Monarch" sand-faced brick-making machine made by Maxted & Knott, Ltd. The clay used in this machine may be freshly dug, weathered, or washed and dug out of the wash-back, according to the circumstances and to the impurities (if any) in the clay. The machine will allow the clay to be in a very soft state, softer even than can be used in a hand mould, or it will also work with fairly stiff clay; but if too stiff the material is liable to stick in the moulds and so cause trouble, or it may break the knives. Sand, similar in every way to that employed in hand-brickmaking, is used for the moulds filled by the machine.

The upper part of the machine consists of a double pug-mill, from which the clay is passed down to the presses and delivered to the moulds immediately beneath it. The action of the presses is somewhat similar to that of the man's fingers and thumbs in hand-moulding and is reciprocating, not rotary. A lad takes the moulds out of a sanding-tank, places them at the back of the machine, and after the clay has been mechanically pressed into the moulds in the front of the machine, the mechanism at the back brings another set into position under the die. A man standing in front of the machine takes the mould and scrapes off the surplus material with a "strike" (p. 53) and hands it to another man, who inverts the mould on to the turn-table and lifts it from the bricks which are thus deposited on pallet boards which have been previously placed upon the turn-table by a lad. The man then turns round, puts the mould in the sander, and

gives the turn-table a push, placing a vacant leaf of the turn-table before him, and placing the loaded leaf opposite another man who takes off the bricks and puts them on to an off-bearing

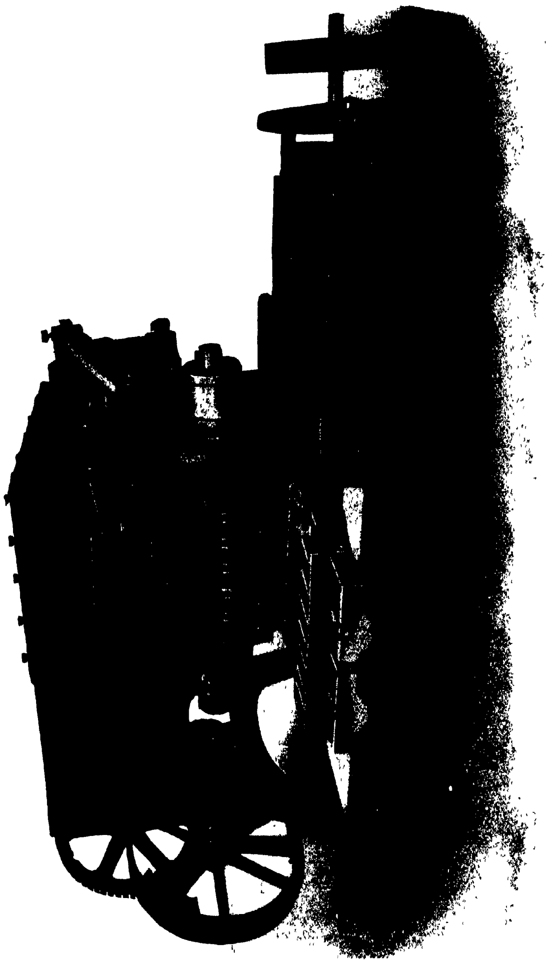

FIG. 30.—"Monarch" brick machine.

barrow or a dryer car as the case may be, five or six bricks being made at a time. The whole operation is very simple and requires no skilled labour.

The amount of pressure exerted on the clay in the moulds can be instantly regulated by moving a small lever in the front of the machine. This lever engages one of several teeth on the cam of the front shaft, carrying the clay presses or "wipers," and therefore determining to what extent the clay in the mould

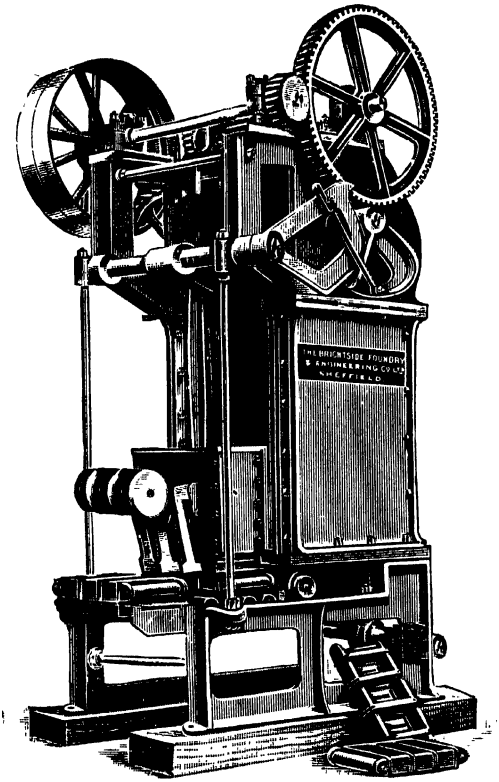

Fig. 31.—Norris brick machine.

shall be pressed. This capability of regulation is essential in order to prevent difficulties due to variations in the stiffness of the clay. When stones and other hard materials are present, they pass out through safety doors controlled by springs at the front of the machine.

The Norris patent mechanical brick-moulder (fig. 31) (made by the Brightside Foundry and Engineering Co., Ltd.) is similar

in many respects to the foregoing, but is of an older type, though a great improvement on many of so-called "soft mud" machines which have been used more in America than here. The clay is mixed in a pug-mill in the upper part of the machine and forced below a plunger. The latter then descends, filling a mould at a stroke and compressing the clay. On the plunger rising, the mould is pushed to the front of the machine, struck, bumped (to loosen the bricks), and their contents turned out on to pallet boards. Each mould makes three bricks at a time, the patentee claiming that this is better, with his machine, than producing a larger number simultaneously. Ample time is allowed for the operation of cleaning, sanding, and replacing the moulds, and effectual means are adopted for preventing the clay displacing the sand as the former enters the mould. The Norris machine requires about 3 h.p. to drive it, and can make 8000 bricks per day under normal conditions.

The "Norris" machine appears to be suitable for making fire-bricks, and can be worked by horse power or by an engine.

In this respect it resembles a larger and more powerful machine (fig. 32) with an output of 20,000 bricks per day, made by T. C. Fawcett, Ltd. The feature of this last named machine is its open construction and large size, whereby repairs and break-downs are reduced to a minimum. It is best worked in connexion with a pair of granulating rolls (which separate small stones) and an automatic sand-moulder, such as the one shown in fig. 33, supplied by the same firm. The addition of a simple belt-conveyer (fig. 34) is often necessary in order to get the clay easily into the machine.

The use of a disintegrator in conjunction with a machine of this kind enables many clays which would be regarded as useless for hand-brickmaking to be satisfactorily worked in a soft-mould machine of the various types described. Even when it is not absolutely necessary a disintegrator is often used, as it absorbs less power in breaking up the clots than would be needed if they were allowed to enter the pug-mill of the machine.

Another moulding machine for sand-faced bricks, suitable for small yards and for places where skilled moulders are difficult to get, is Eddington's Moulding machine (fig. 35), made by James Buchanan & Son. Like the machine just described, it forces a column of clay into two sanded moulds, each of which is filled alternately. The clay is cut off by a wire drawn across the mould, which is then moved forward. The surface of the brick

is smoothed with a strike, the mould opened, and the brick placed on the pallet ready to go to the dryer or hack. The special feature of the Eddington machine is the mould, which is specially designed to overcome the difficulty usually experienced

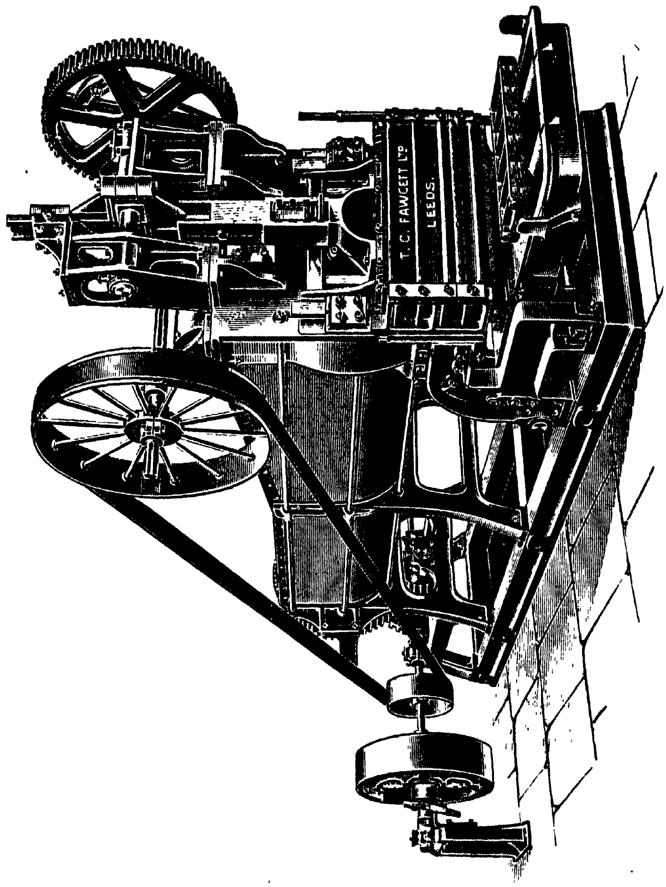

FIG. 32.—Anglo-American brick machine.

in emptying box moulds. On this account, the sides of the mould are made in two pieces connected in such a manner that, on moving two small arms or triggers, the mould expands and leaves a clear space all round the brick (fig. 36).

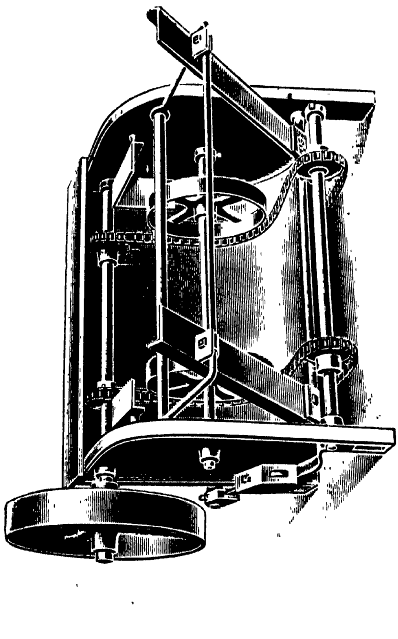

FIG. 33.—Mould-sanding machine.

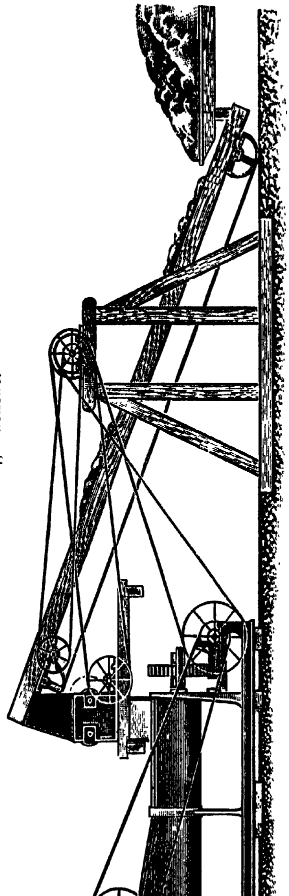

FIG. 34.—Arrangement of plant for machine-moulded bricks.

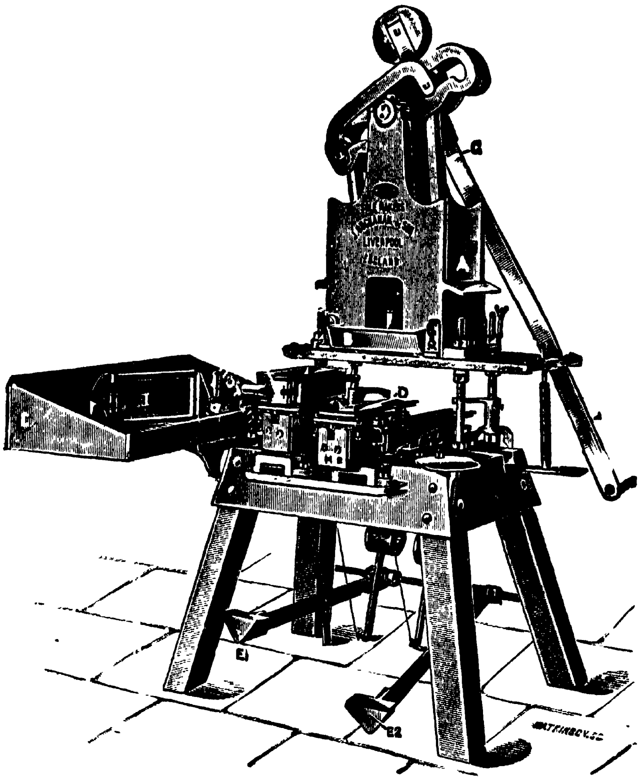

FIG. 35.—Eddington's moulding machine.

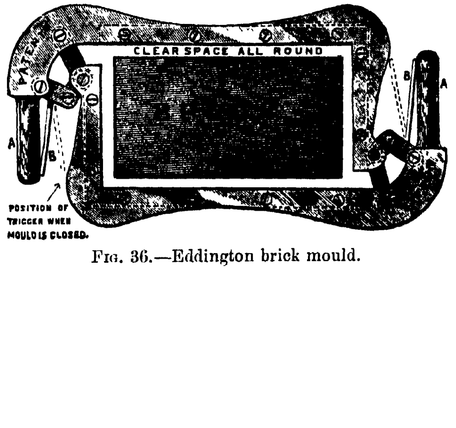

FIG. 36.—Eddington brick mould.

This machine produces a good square brick, free from sand folds, though not of quite so good a colour as a hand-made sand-faced brick. It is made in two sizes, the No. 2 machine having an output (according to the makers) of 3000 to 4000 bricks per day.

WIRE-CUT BRICKS.

An entirely different method of manufacturing bricks is that in which the wire-cut system is employed, the clay being thrust out of a pug-mill in the form of a belt or band of clay, 9 ins. wide by 4½in. high, which is cut into bricks by means of wires or rotating knives. Bricks made by this process are equal in shape to those made by hand, and the rapidity and ease with which they can be produced by unskilled workmen, is such as to make this method exceedingly popular. It is particularly suitable for clays worked up into a plastic paste of moderate stiffness, but can, on occasion, be used in connexion with what is ordinarily known as the "stiff-plastic process". It is especially intended for earths which do not require washing or other preliminary treatment in order to purify them.

The underlying principle involved in making wire-cut bricks is the conversion of the clay into a paste and passing it through a pug-mill, or closed mixer, to the discharge end of which a die is fitted. The successful manufacture of wire-cut bricks depends upon the durability and accuracy in shape and size of the die, the ease with which the clay passes through it, and the extent to which consolidation is produced without lamination. Whilst apparently simple, the wire-cut method of brickmaking offers many difficulties to the inexperienced brickmaker, and it is therefore described fully in the following pages.

Almost any clay which can be made into a plastic paste of sufficient stiffness can be made into wire-cut bricks, providing that it is sufficiently finely ground. The custom of permitting pieces of stone and other hard material of more than one-sixteenth inch diameter to get into the machine used for this purpose is unsatisfactory, as the wires are unable to cut this material, and the cut faces of the bricks are thereby rendered unsightly.

There is a great temptation for brickmakers to employ rolls to crush everything taken from the clay-bed without regard to its nature, but this practice is detrimental to the production of good bricks; so that whilst rolls are invaluable for enabling materials to be used which cannot, otherwise, be employed in brickmaking, they do not by any means abolish the necessity for care in the selection of materials.

Opinions differ greatly as to how far grinding is necessary, but the author is convinced, as the result of extensive observation and wide experience, that clay for making wire-cut bricks should always be sufficiently fine to pass through a sieve having twelve to twenty holes per running inch. Coarser ground materials are never, in his experience, really satisfactory. The clay,

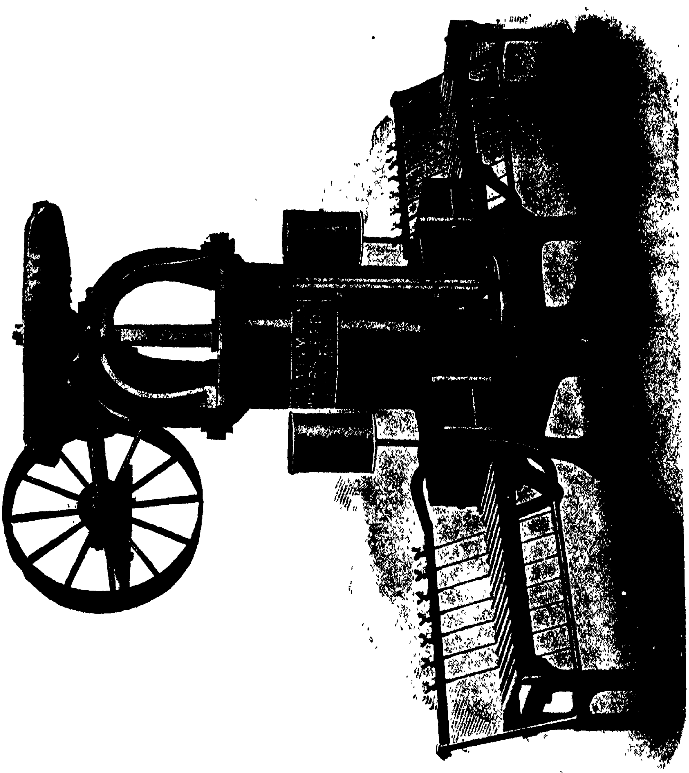

Fig. 37.—Vertical brick machine. Type *a*.

which should preferably have been weathered (page 22), may be treated in a variety of ways according to its nature and the impurities in it, and nothing less than a good knowledge of the material itself will enable a man to state the exact treatment necessary.

The following are the most important arrangements of plants for the manufacture of bricks by the wire-cut process for plastic clay:—

(*a*) *A Pug-mill with Mouthpiece or Die, and Cutting Table* (figs. 37,

38). This is very suitable for clean clays which are not too strong or sticky, and is specially good for loams of good quality. It is the final portion of all the plant used for wire-cut brickmaking, and simply effects a mixture of the clay and water so as to form a

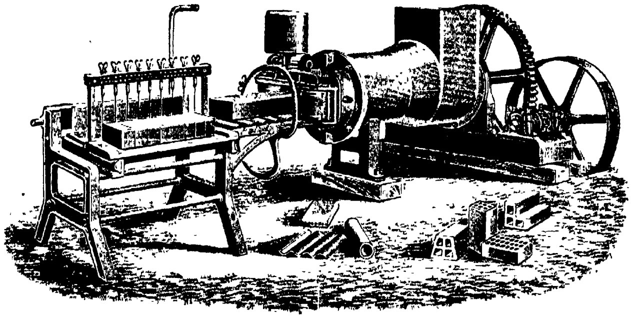

FIG. 38.—Horizontal brick machine. Type *a*.

homogeneous paste, and shapes this by forcing it through the mouthpiece on to the table where it is cut into bricks. It can, if properly arranged, be enlarged by the addition of rolls and mixers.

(*b*) *Pug-mill, Expression Rolls and Cutting Table* (fig. 39). This

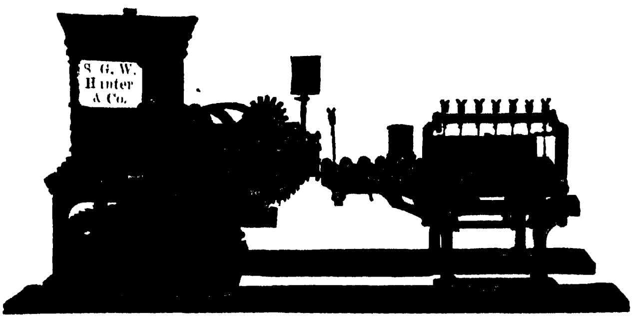

FIG. 39.—Brick machine. Type *b*.

arrangement is specially used for clays which tend to produce a core or lamination when the die is attached direct to the pug-mill.

It is only suitable for clay free from hard and stony matter, and is most adapted for use with strong plastic clays. Either a horizontal or vertical pug-mill may be used.

(*c*) *Crushing Rolls, Pug-mill, Die, and Cutting Table* (fig. 40). This arrangement is used where the brick earth is strong (plastic), and contains hard lumps of clay or stones. It is suitable for

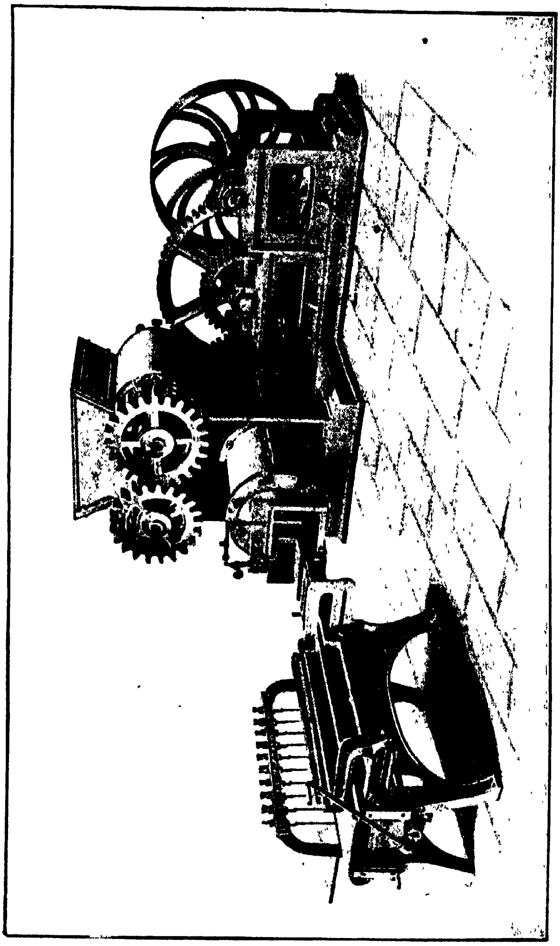

FIG. 40.—Brick machine. Type *c*.

materials which cannot be made into bricks by simple pugging, on account of the hard portions just mentioned, as these would catch the wires of the cutter and would produce an unsightly

brick. About 10 h.p. is required for a daily output of 20,000 bricks under good conditions.

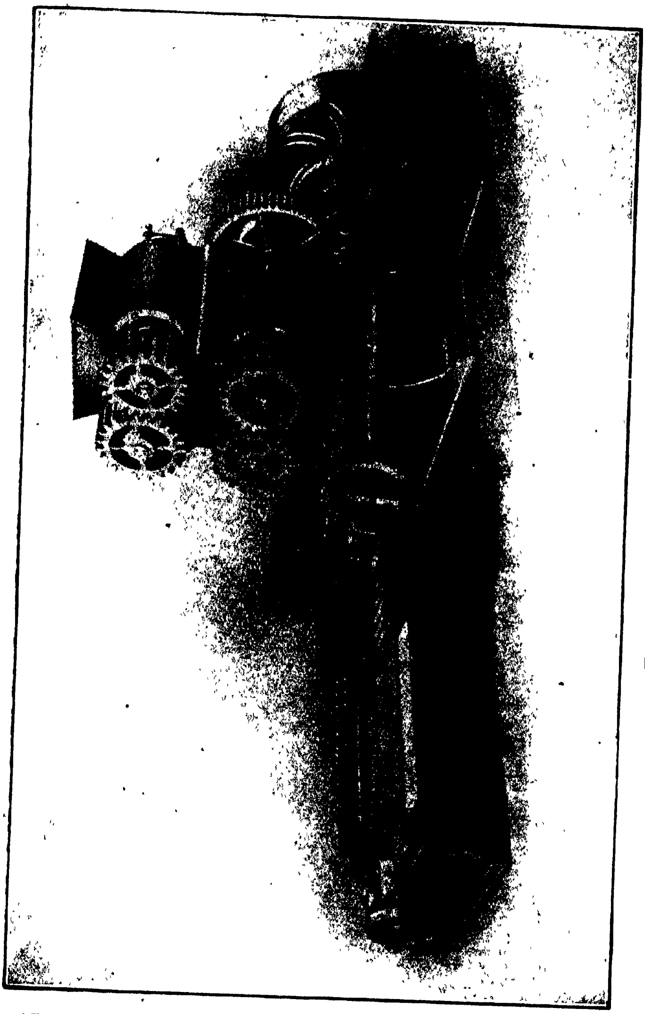

FIG. 41.—Brick machine. Type *d*.

(*d*) *Two sets of Rolls, Pug-mill, Die, and Cutting Table* (fig. 41). This plant is used for similar earths to that described in (*b*) but the additional rolls enable rougher and more difficult materials

to be treated. Usually the upper pair of rolls is provided with grooves—see figs. 46, 53 and 54—which prevents the clay from adhering and so being carried round the rolls (see "Kibbler Rolls").

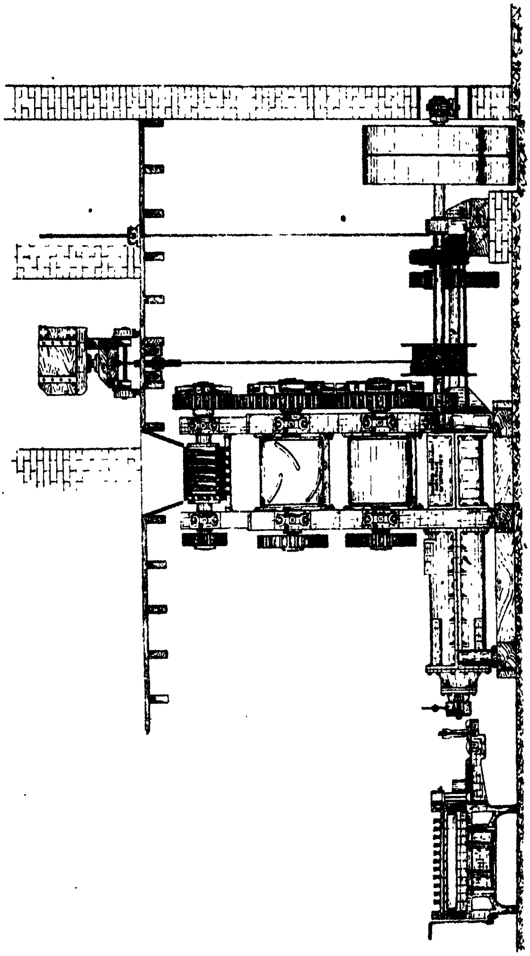

FIG. 42.—Brick machine. Type e.

The second rolls are smooth and set much closer together than the first ones. 15 to 30 h.p. is needed for a daily output of 20,000 bricks.

(e) *Three sets of Rolls, Pug-mill, Die, and Cutting Table* (fig. 42).

This plant is used where hard stones or lumps of hard clay are present in such quantities that a smaller number of rolls is insufficient to crush them. The first (uppermost) pair of rolls is usually grooved or spiked, the second pair being set $\frac{1}{4}$ to $\frac{1}{2}$

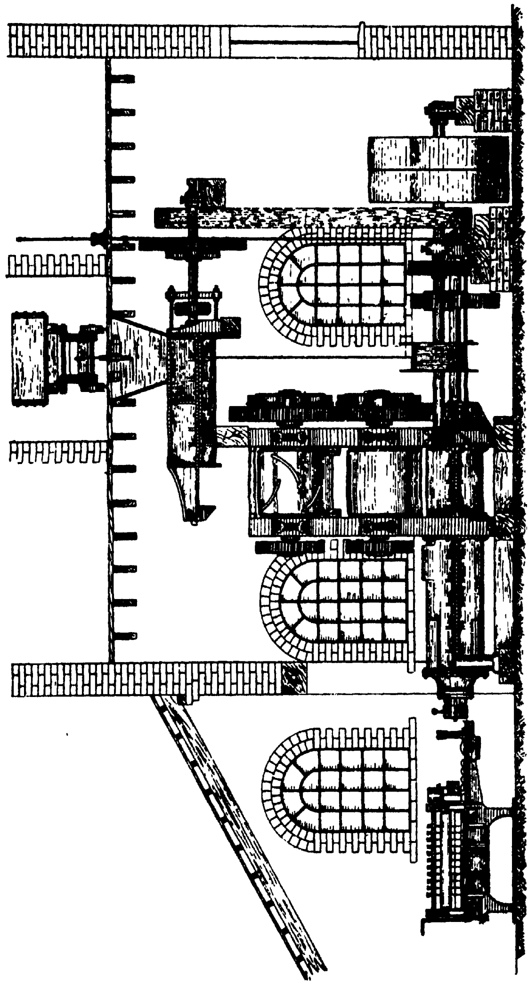

FIG. 43.—Brick machine. Type *f*.

in. apart and the third pair as close as possible. About 30 h.p. is required to drive this plant effectively.

(*f*) *A Feeder or Mixer, two or three sets of Rolls, Pug-mill, Die, and Cutting Table* (fig. 43). This is similar to arrangements (*c*) and

(*d*) but is preferable where several clays are mixed together, or where the clay is of a very varied character. The feeder, or mixer, effects a preliminary mixture of the material and, by supplying it in a regular quantity to the rolls, makes it easier to keep the machine working under the best conditions. The power required to drive this machine is about 50 h.p.

(*g*) *Grinding Mill, Rolls, Pug-mill, Die, and Cutting Table* (fig. 44). In place of a mixer as in (*e*) it is sometimes better to use a grinding pan, particularly if the earth contains much material of a rocky or gravelly nature. The employment of a grinding mill in connexion with the plant is also advantageous when the earth is somewhat deficient in plasticity, and would otherwise require much tempering. In this arrangement the clay is delivered as regularly as possible into the mill where it is mixed

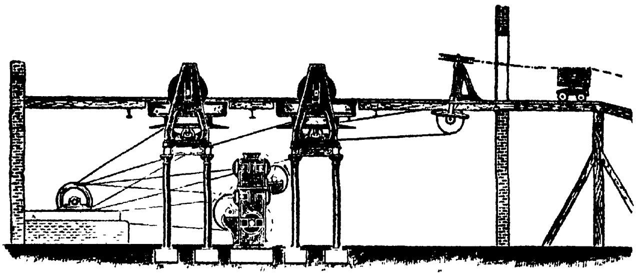

FIG. 44.—Brick plant. Type *g*.

with the necessary quantity of water. After being ground and mixed by the action of the mill runners, it passes through a grid in the bottom of the pan to the rolls and thence to the pug, die, and table. Such a plant will require 60 h.p. to yield an output of 20,000 bricks per day.

(*h*) *Feeder, Grinding Mill, Rolls, Pug-mill, Die, and Cutting Table.* (fig. 45). This is the same arrangement as (*f*), but fitted with a preliminary mixer or feeder. This addition greatly improves the quality of the bricks when several clays are mixed, or when a complex earth is used. Such a plant will often work satisfactorily with unwashed London clay when others have failed, and it is specially adapted for use with very strong and sticky clays. The power required to drive varies with the clay or earth used, but is about 55 h.p. for a daily output of 20,000 bricks of strong clay; with milder earths it is less, as one pair of rolls may be omitted.

(*i*) *Rolls, Mixer, Two more sets of Rolls, Pug-mill, Die, and Cutting Table* (fig. 46). This arrangement of plant is suitable for some strong clays, marls, or shales, where repeated crushing and mixing is needed, or where the use of a grinding pan is impracticable on account of the excessive hardness of the material and the impurities it contains.

When two sets of rolls are set before the mixer, or when the material is passed through two sets of rolls before entering the pug-mill, the usual arrangement for Staffordshire is obtained (fig. 47). This gives the material an exceedingly thorough treatment, and owing to the amount of power required should only be used when absolutely necessary.

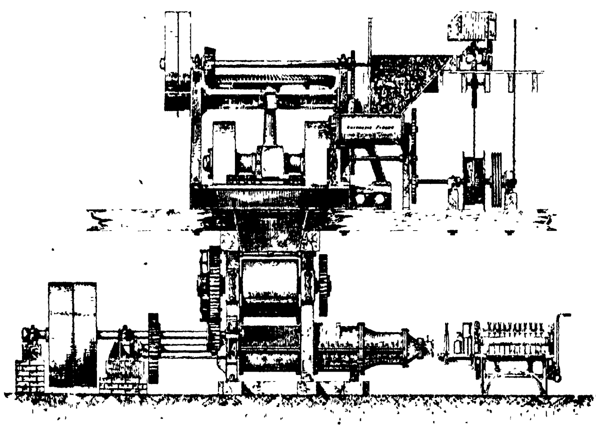

FIG. 45.—Brick plant. Type *h*.

When the full set of plant just mentioned is used, the hardest materials can be fully ground and tempered. Somewhat softer earth can be more conveniently treated by the plant referred to in (*f*), (*g*), or (*i*).

(*j*) *Feeder, Grinding Mill, Rolls, Mixer, Rolls, Pug-mill, Die, and Cutting Table* (fig. 48). This forms a suitable plant for hard materials which require much tempering, but for which it is not necessary to use the arrangement (*h*), though that described under (*f*) is not sufficiently strong in tempering or mixing power.

(*k*) *Grinding Pan Mixer, Pug-mill, Die, and Cutting Table.* This is a simplified arrangement of (*i*) and can be used for materials of considerable, but not excessive, hardness. It is capable of

developing the plasticity of lean materials to a remarkable extent and is specially recommended for fire-clay and shale, these materials being screened before they enter the mixer.

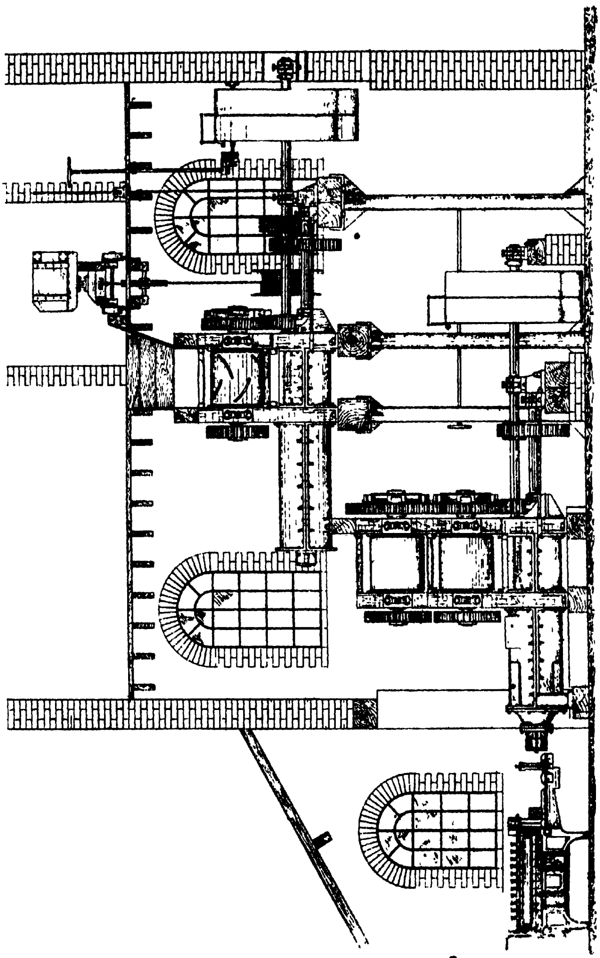

Fig. 46.—Brick plant. Type i.

Selection of Plant.—The selection of the plant to be used for a given material must depend largely on the nature of the latter, and particularly on its hardness and plasticity. It is wise to so

arrange the plant that additional rolls or mixers can be easily applied, if necessary, but these should not be purchased until they have been found to be really necessary. Many brickmakers use too much machinery for their work, and a study of the requirements of certain earths often enables a brickmaker to effect a considerable saving in the amount of driving power required. Whatever arrangement of plant is used it is essential that it shall be strong, well made, and of good design and materials. In this connexion the following information about the

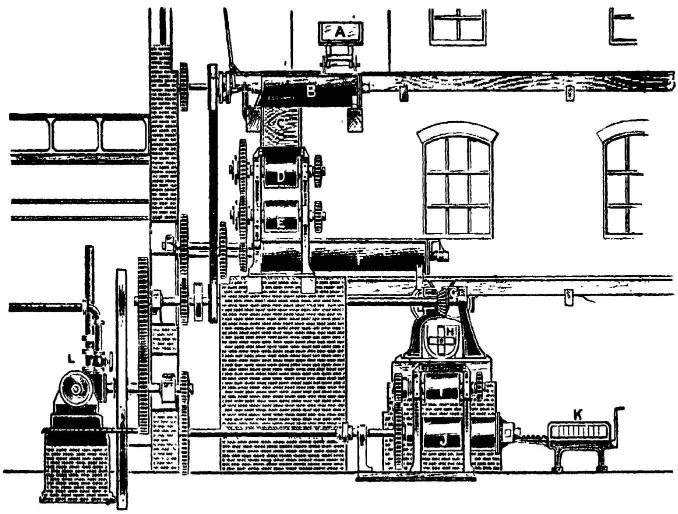

FIG. 47.—Plant (Type *i*) for Staffordshire "marls".

various portions of machinery required in the foregoing arrangements of plant may be useful.

Crushing Rolls (fig. 49) are employed for reducing clays which are too moist or plastic to be ground by other means. Dry or hard clays are preferably treated in an edge-runner mill, particularly if a stone breaker is used as a preliminary crusher. These rolls consist of a pair of strong cylinders, or rollers, usually smooth and placed side by side, so that when the clay is fed on to them the rotation of the rolls forces the clay downwards and reduces it to a size comparable to the distance between them. They are driven by a simple gearing through a belt or clutch.

Both rolls in a pair may be driven at the same speed or one

may rotate faster than the other, this latter having the advantage of giving additional crushing power with sticky clays, owing to the increased rubbing action.

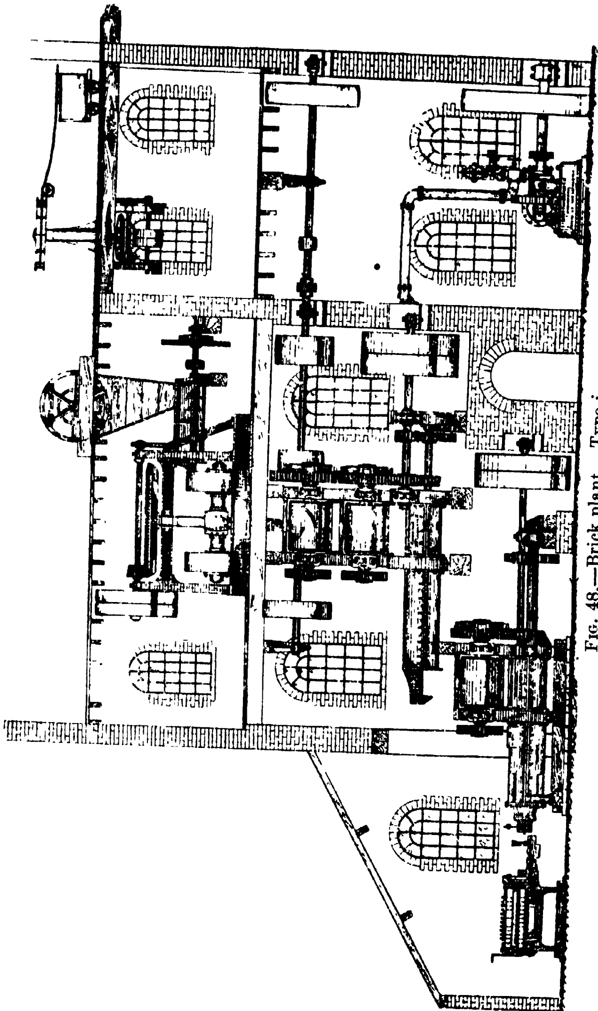

FIG. 48.—Brick plant. Type j.

Crushing rolls require a considerable amount of power to drive them, and they are subject to violent strains. Lumps

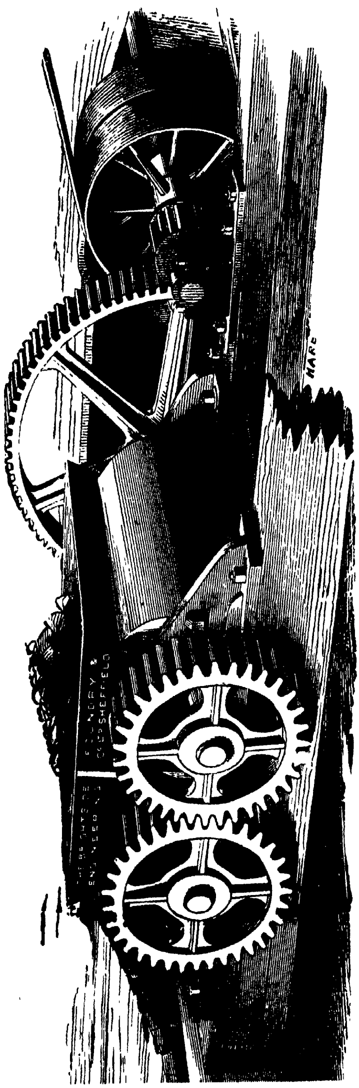

Fig. 49.—Crushing Rolls.

larger than a man's head occasionally have to be dealt with, but it is safer to break these by hand. It is, therefore, necessary to have the roller machinery built very rigidly with no skimping of metal for the sake of cheapness. The strong thrusts of the machine must be properly taken up by suitable ties, springs, and bearings, and each part must be readily accessible for repairs and renewals.

Rolls vary considerably in size, being from 18 in. to 24 in. in diameter and 2 ft. to 3 ft. long and are made of specially hardened iron, soft iron cores cast in iron chills, or of iron cores with steel rims. A particularly ingenious method is that employed by John Whitehead & Co., Ltd. This construction enables a shell of any desired hardness to be used, and this is fixed truly in position on the shaft by means of the two cast iron ends with bevelled edges. These ends are drawn together (after

the shell has been placed over them) by means of two iron bolts. A boss on the inside of the shell locks into a projection on the left end and prevents the shell turning independently of the shaft.

Instead of the rolls being true cylinders and of the same diameter throughout they may be conical in shape. This enables them to automatically throw out a portion of the stones in the clay which, with cylindrical rolls, would be ground up. Only large stones can be separated in this manner. It is often convenient to make rolls in three or more portions, so that as one of these wears away only a portion of the roll needs renewal, and

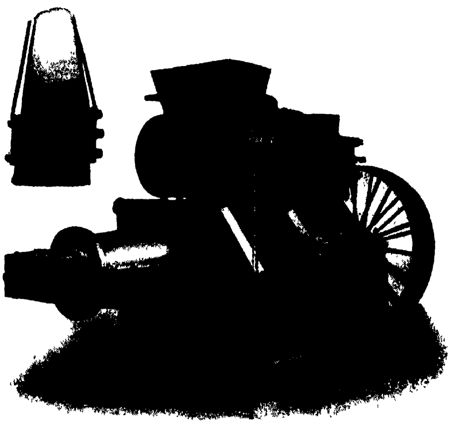

FIG. 50.—Rolls with interchangeable sections.

by interchanging the centre and other rolls the need for new ones may be indefinitely delayed.

Rolls of this type are a feature of the "Lancashire" machine made by Sutcliffe, Speakman & Co., Ltd. (fig. 50). In this, the sections are all made interchangeable, so that as the centre sections wear they can be placed at the outer ends of the rollers and the end sections placed in the centre. Brickmakers who have any stony materials to deal with much appreciate this arrangement, as on the old system the rollers always wear away in the centre and do not permit of them being closed up unless the rollers are taken out and turned up in the lathe. The sections should be rearranged frequently, even if little wear is shown, so that the rollers will wear parallel. To enable this to

be readily done all the gearing is so placed that one frame only requires unbolting, when it can be drawn away, as shown, to permit of the sections being placed as desired.

The rollers in this machine are made large in diameter and narrower than is the usual practice, and as they run at a high speed the clay is very well ground. One roller is made to go at a greater speed than its fellow, this giving a differential shredding action.

All rolls should be provided with a relief escape, or a safety slipping clutch to prevent the risk of breakage should a piece of ironstone or other hard metal get into the machine by accident, or should the resistance to crushing be so great as to endanger the machine. Instead of two sets of rolls arranged one below the other, some firms employ three rolls so placed that the clay receives two distinct crushings. Machines of this type are shown in figs. 51 and 52.

A hopper is often desirable to secure the material being fed into the machine properly; end plates will serve to prevent its escaping. Scrapers are sometimes necessary when sticky clays are being crushed.

Lubrication is of great importance, and if neglected will cause a great waste of driving power.

For good work it is essential that the rolls should run truly, with no variation in the space between them, and some simple method of adjustment should be provided to enable them to be set closer together when slightly worn.

The distance of the rolls from each other in each pair is important. If only one pair of rolls is used they cannot well be set closer than half an inch, but if two or more pairs are employed the first should be moderately wide apart—up to 2 in.—the second should be closer, and the final pair should be set as closely as possible. Some brickmakers work with all the rolls too wide apart; this is foolish, as it permits stones to be mixed with the clay and to be made into bricks, and it is then impossible to make goods of best quality. To obtain satisfactory results, the clay should come from the crushing rolls in the form of a thin sheet, like coarse brown paper. It is almost impossible for a single pair of rolls to produce this.

The rolls should be made of chilled iron or steel, or covered with a steel hoop truly turned with a lathe, but for the coarser rolls this accuracy is unnecessary, as they are not intended to

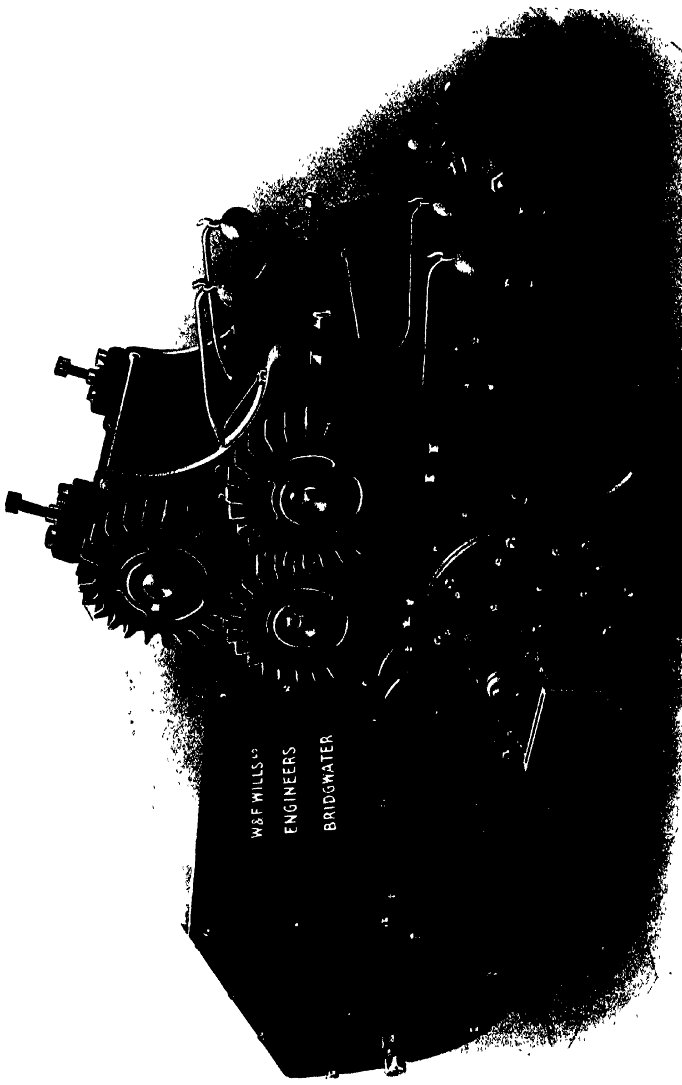

FIG. 51.—Triple-roll crusher.

crush the clay so thoroughly. Steel-rimmed rolls are always more desirable than those of chilled iron.

Close-set rolls must be kept true in shape, and when they are used it is necessary to have an extra pair of rolls which may be used whilst the worn ones are being turned true. Rolls which are supposed to be run close, but which have a wider opening in the centre than at the edges, are useless for good work. It is desirable that rolls which are intended to work close together

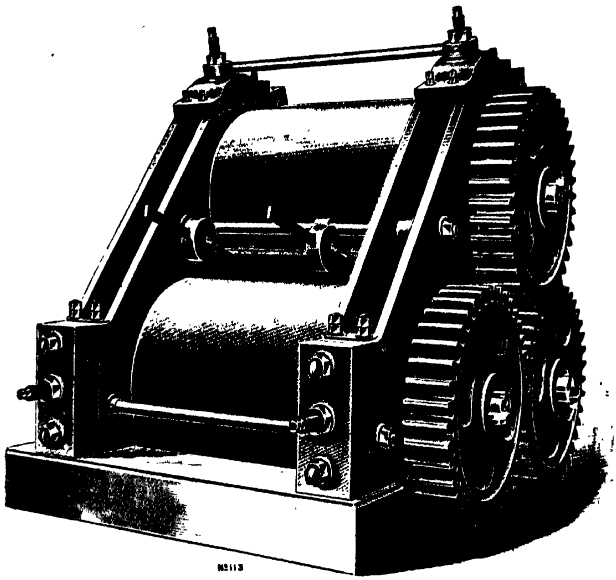

FIG. 52.—Buchanan's triple-roll crusher.

should be provided with renewable rims so that these may be replaced when necessary. More difficulties in working certain clays arise from worn rolls than from any other single cause; the rolls should therefore be frequently examined.

Crushing rolls are usually smooth but, for preliminary crushing, rollers with projections, bars, teeth, flutes, grooves, corrugations and other uneven faces are employed. Sticky clays require these irregular surfaces, as smooth rollers do not possess enough adhesive power to crush the material. The nature of the projection is largely a matter of individual taste, though the

greater the projection the greater the power of the rolls. Hence teeth and bars are better than grooves for sticky clays, but corrugated or grooved rolls are best for stony clays.

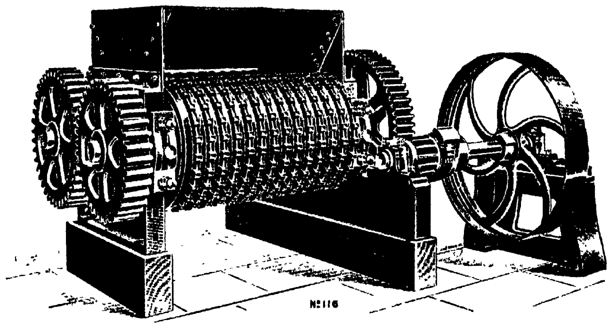

FIG. 53.—Toothed crushing rolls (Whittaker).

Many designs of projections and grooves are in use, some of them being comparatively valueless. Amongst the best are hedgehog (toothed) rolls (fig. 53) kibbling rolls, (fig. 54) and corrugated rolls.

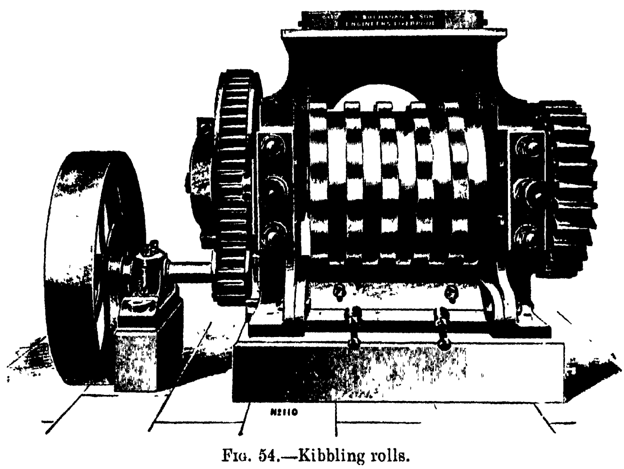

FIG. 54.—Kibbling rolls.

The projections on one roller engage with those on another, and the combined action of the two on the clay is much more powerful than when smooth rolls are used. The material is

caught between the projections, and being unable to escape is crushed sufficiently to enable a succeeding pair of smooth rolls to deal with it effectively.

Broad spiral corrugations running right and left hand respectively, throughout the entire length of the rolls, often increase the rapidity with which a sticky material may be crushed, and the larger portions are conveyed to one end of the rolls and drop into a special receiver. According to their nature these portions may be discarded, as stones, or may be reduced by hand or other means. The use of corrugated rolls is, in fact, one of the simplest methods of separating stones from clay. The corrugations should be so arranged that the projections in one roll should fit into the depressions of the other, so that wear may be compensated and the rolls kept set close together.

For stony clays of a sticky and tough nature the rolls should be both corrugated and conical; this is far superior to the use of smooth conical rolls, as the corrugations convey the material to the large ends of the cones where the clay is crushed in consequence of the greater peripheral speed. High speed rolls with projections are popular in America, and are very efficient for clays which are not too hard. The rolls should be made in sections for easy renewal, as the wear on them is much greater than in a slower machine. This is fully balanced by the increased output and the condition of the product. The projections or lugs should not go the whole length of the roll, but should have intervals between each. By rearranging the worn sections on the same roll the wear is more evenly distributed.

The use of crushing rolls is simple enough, provided that the works possess the means of having them trued and properly set; otherwise they may cause much trouble through their not crushing the clay sufficiently, and in such cases it may happen that an edge-runner mill will give better results. This is not always the fault of the rolls, but often of the clay or the man in charge. It is of the greatest importance in making wire-cut bricks that the material should be finely ground and entirely free from lumps. The size of the particles should not, on the other hand, be excessively small.

Grinding Mills or *Edge-Runners* are of two main classes: (1) Those used for crushing dry materials to a powder and known as "grinding mills," and (2) those employed for crushing moist or wet materials, and at the same time mixing them so as to obtain a more uniform composition, and known as "wet pans" or (less

correctly) "pan mills". Both classes of mill are used in the manufacture of wire-cut bricks made by the plastic process, but for convenience mills for grinding dry material are described in Chapter V in the section on "stiff-plastic process". Their sole purpose is to reduce the material to a fine powder, and in certain cases, which are difficult to classify, they work more economically than do crushing rolls, as the full weight of the roller or runner is available for crushing. Broadly speaking, a hard material, fairly free from sticky matter, is most economically ground with an edge-runner mill, but if much moist plastic clay is present it is usually better, and often essential, to use crushing rolls and a wet pan.

Wet Pans are chiefly used to secure an equal distribution of the moisture throughout the clay mass and to secure the latter being of the same composition throughout. For this purpose it is passed many times underneath the rollers before it leaves the machine, whereby any lumps are simultaneously reduced to powder.

In many cases the material is fed into the pan of the mill, a suitable quantity of water added, and the pan kept in motion from fifteen to twenty minutes. The speed is then reduced, and the material removed by means of a special shovel working in a rowlock.

Continuous wet-pans are well known, but are considered to yield a less satisfactory product. They have a bed, or pan, perforated near the centre, and the material is forced to travel several times under the runners before it can escape through the holes. The most important features of a wet-pan are the weight and size of the runners, the construction and speed of the pan, and the transmission arrangement for driving the machine. It is essential that the runners should be heavy; those supplied by many firms are much too light to do their work effectively. For a 9 ft. pan the runners should seldom weigh less than 40 cwt. each, and for some clays they should weigh about 4 tons if a satisfactory product is required in a reasonably short time.

The construction of wet-pans in this country is quite different from that considered best in some others, and several British makers of machinery recommend the stationary wet-pan for certain clays, in spite of very conclusive evidence of its inferiority to the rotary one for this purpose.

A typical stationary pan is shown in (fig. 55). It consists

of two heavy runners and two scrapers mounted on a single shaft and driven by means of an overhead crown wheel and

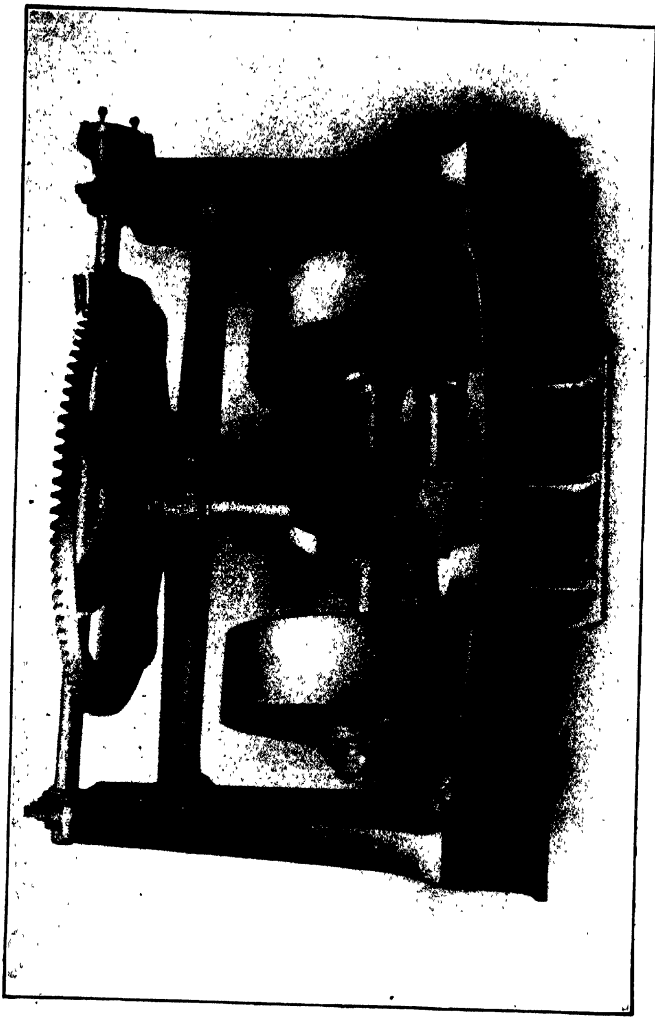

Fig. 55.—Wet grinding pan (Bradley-Craven).

pinion. A grid is fixed in the pan, and the material passes through this as soon as it has become sufficiently softened to do so.

The mixing power of such a mill is relatively small, its chief use being to reduce the material to a form in which it can be more readily dealt with by succeeding plant than if the clay were fed direct to the latter. Its efficiency depends largely upon the smallness of the grid and, therefore, the extent to which the material is treated before reaching it.

For some materials such a pan may be improved by inserting a solid bottom and removing the material (after the mill has been stopped) either by means of a spade or by opening a sliding door in the bottom of the mill.

Sutcliffe, Speakman & Co., Ltd. have designed a special mill for material which is free from large lumps, but requires an unusual amount of mixing. The material is fed into an attachment on the side frame just below the crown wheel. From this it passes to a small pan, fixed to the upright shaft, which ensures the material passing under the rollers where it is kneaded and rubbed together, thus giving a very intimate mixing. The material in the stationary pan on which the runners revolve is turned over by multiple scrapers which gradually push it to the discharge opening

According to the nature of the material supplied this will mix two to five tons per hour using 8 h.p. for driving.

A wet-pan of more modern design is shown in fig. 56. The pan (9 ft. diameter) is mounted on an upright shaft working in a footstep bearing, and kept in position by a bridge-bearing above. It is not perforated, has no grid, and is driven by means of an ordinary crown wheel and pinion and belt, these being placed above (fig. 56) or below (figs. 57 and 124) according as it is more convenient to have the pan over-driven or under-driven. The bottom and sides of the pan are renewable.

The runners for a pan of this size are 4 ft. 8 in. in diameter with 15 in. width of face and weight 43 cwt. each; they are preferably made with flush sides so as not to carry up any ground material, and may be fitted with renewable rims. The ends of the shaft connecting the runners to the centre block work in guides which permit the runners to rise and fall with varying thicknesses of materials on the pan but prevent them rotating above the vertical shaft. If two shafts are used—one for each runner—they can rise or fall independently of each other, thereby saving power and keeping the machine in better balance. The runners revolve by the action of the material on

the pan and are not driven directly. They should not touch the pan when it is empty but should be just clear.

The scrapers should be attached to cross stays bolted on to the framework of the machine, and must be so fastened that they can be turned to any desired angle and adjusted to any height above the pan.

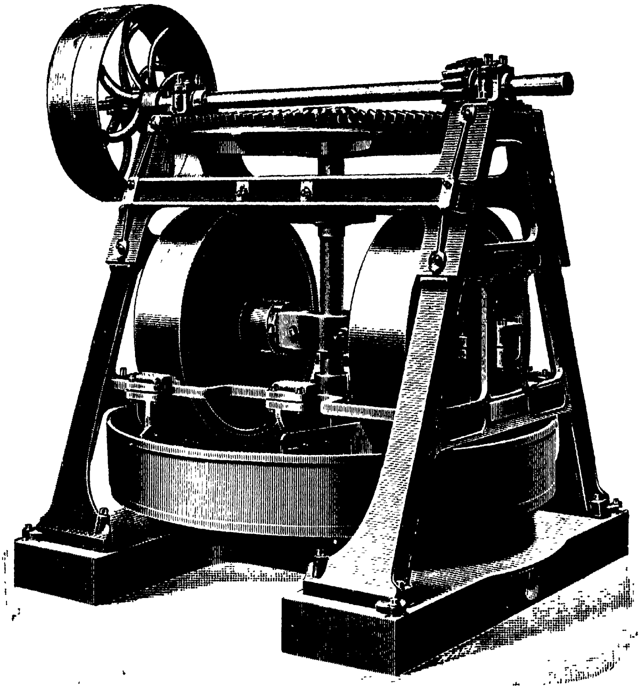

FIG. 56.—Whittaker's revolving wet pan.

When sticky clay is being ground it is useful to have scrapers attached so as to keep the runners fairly clean (fig. 58), as no purpose is served by runners thickly coated with clay. These "cleaners" should not actually touch the rims of the runners, or too much iron may get into the clay.

The footstep is an important factor in successful grinding. It should be readily accessible, easily lubricated, and of such construction that the bearing metal can be easily renewed

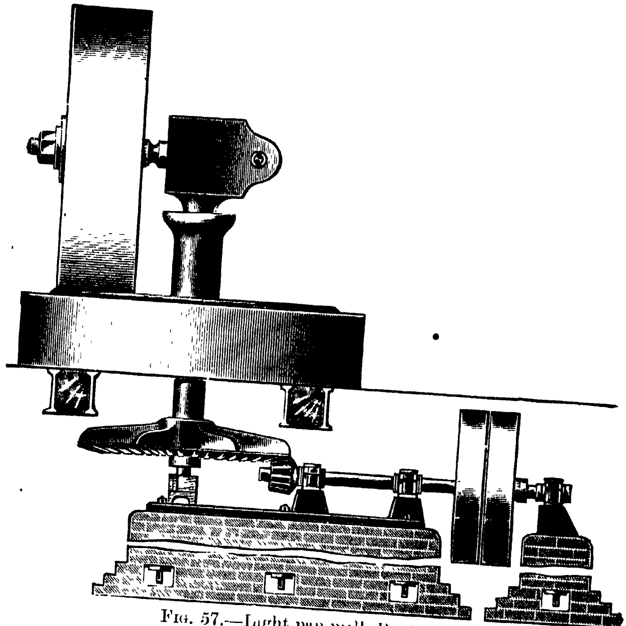

FIG. 57.—Light pan mill (Boulton).

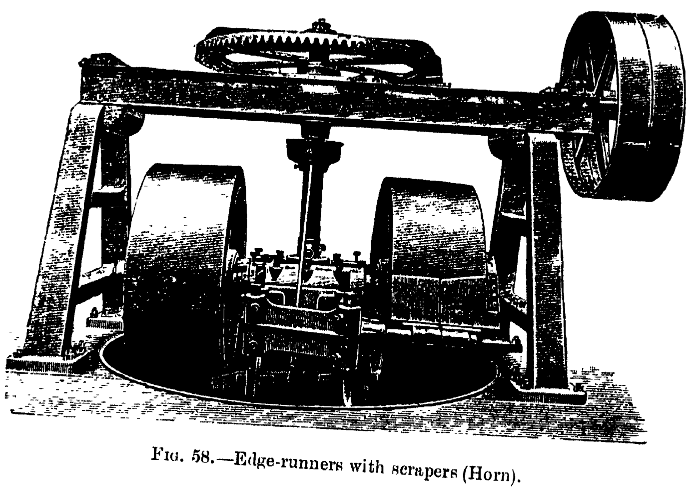

FIG. 58.—Edge-runners with scrapers (Horn).

when worn. It should be cased to keep out dust, but should be examined frequently, as a worn footstep causes much loss of power and may easily damage the pan. Anti-friction rollers should be placed underneath very large revolving pans in order to support them. The pan should be light but strong, and provided with a loose bearing ring, or false bottom, preferably of manganese steel. There are advantages in having this bottom ribbed for soft clays, but with very hard ones it is undesirable. A mechanical shovel is used for removing the material except in self-delivery mills.

A measured quantity of the material to be treated is placed in the pan, a definite volume of water added through a sprinkler, and the pan set in motion at a speed of sixteen to forty revolutions per minute according to the nature of the clay. After fifteen or twenty minutes the speed is reduced and the mechanical shovel used to withdraw the material, after which a fresh batch is treated. Unless the clay and water are both measured, the paste will vary in stiffness and plasticity. To avoid loss of time, it is wise to have two mills and to run them consecutively. By the insertion of a slotted grid in the roller path the material may be delivered to a receiving plate, whence a fixed scraper removes it continuously to the next stage of manufacture.

Runners with a conical instead of a flat face (fig. 59), may be used for wet grinding. It is understood that they have a somewhat larger output, but this has not, so far as the author is aware, been definitely proved.

For clays containing a large proportion of small stones, especially if the latter are of a limey character, J. Buchanan & Son, Ltd., recommend the use of a wet grinding pan of the stationary type. In this pan (fig. 60) the runner path consists of six or more manganese steel grids, the space between each being fitted with steel plates—either smooth or corrugated—the mesh of the grids being adjusted to the requirements of each clay.

The runners are made of hard cast iron and run upon hard cast iron renewable bushes; they are carried upon a square steel shaft provided with slide blocks to rise and fall in the slotted cross-head of the vertical shaft.

Steel scrapers are attached to the cross-heads, and revolve with it, for throwing the material from the outside and centre of the pan on to the runner path. The mill is driven with strong bevel gearing by a steel driving shaft working in gun-metal bearings, and fast and loose pulleys.

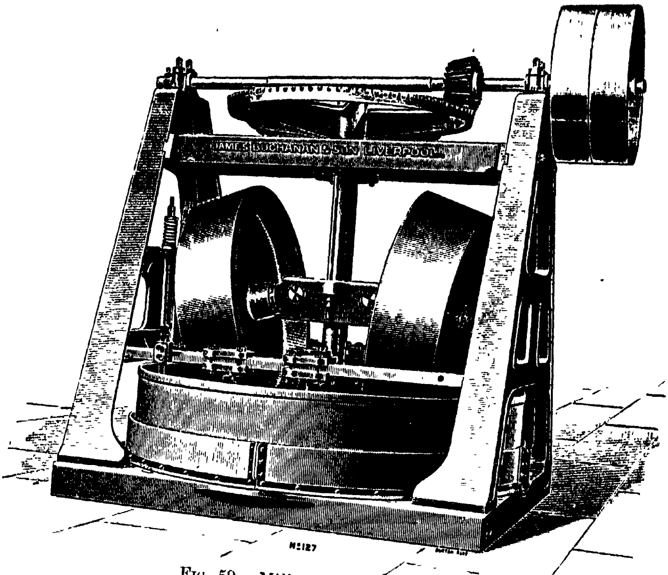

FIG. 59.—Mill with conical runners.

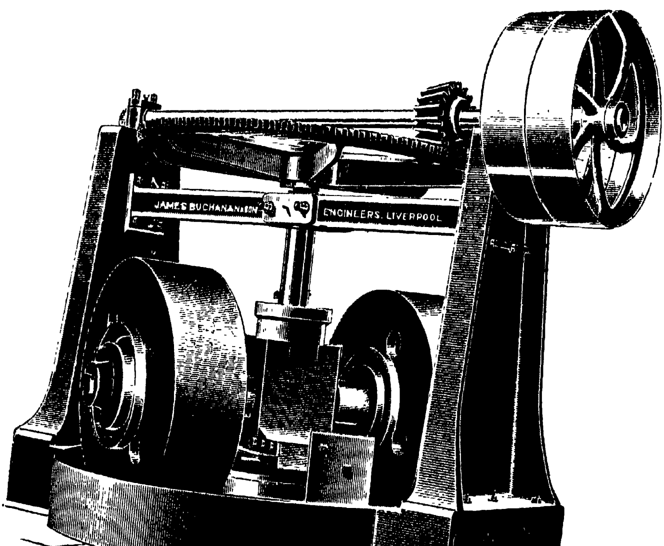

FIG. 60.—Mill for limey clays.

Where strong plastic clays containing large quantities of lime and other stones (as boulder clays) are to be found, the use of a stationary wet-pan of this type as a preliminary grinder and mixer is desirable, as revolving pans are too lightly constructed for this class of work. The material should afterwards be passed

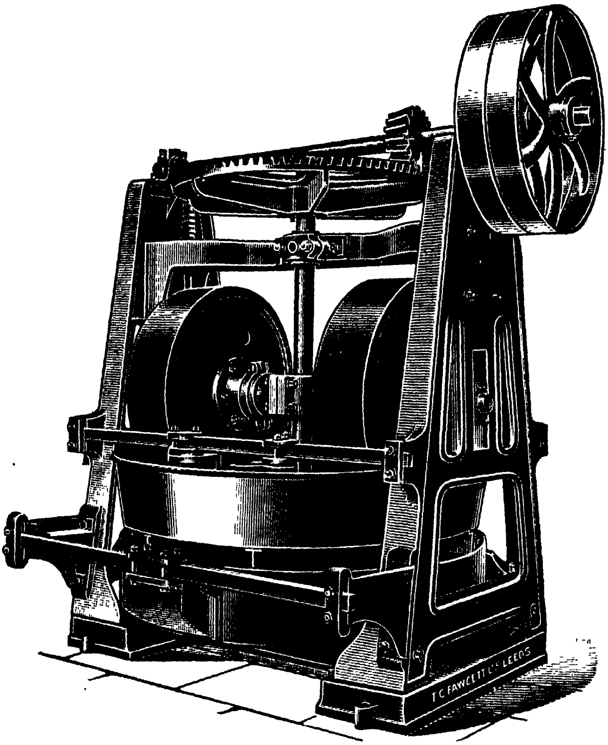

Fig. 61.—Continuous self-delivery wet mill.

through two sets of rollers before entering the pug-mill. The grids require frequent inspection, and should be made of manganese steel as this possesses the greatest resistance to wear and tear. They should be easily renewable.

The mill shown in fig. 61 is one made by Thomas C. Fawcett, Ltd., who state that it is distinct from other plastic pans in that both the rolls and pan revolve, and the material,

after being ground and mixed, is delivered on to a receiving plate which is keyed on to the vertical shaft, and, revolving with the pan, delivers the material by means of a fixed scraper direct to the brick machine. The pan is 9 ft. in diameter and the power required to drive it is 20 b.h.p. It is claimed that this machine will give an output equal to other machines but through smaller grids, thereby ensuring finer grinding and tempering of the material without increasing the cost of treatment. Pan-mills mix the water and clay more thoroughly than do pug-mills using the same driving power, but the texture of different batches of paste is more irregular.

MIXERS AND FEEDERS.

After the material has passed through crushing rolls or some other form of preliminary grinding plant it must enter a mixing machine. For some clays a mixer forms the first part of the plant and it is then known as a feeder, though, mechanically, it is really a mixing machine. The object of using mixers and feeders is to produce a material of even composition from a number of different materials which may occur together in nature—as is the case of clay with stones or sand in it—or which may occur separately, but which it is desirable to mix, as when certain properties are to be conferred on a clay which can only be given by adding other materials to it.

Broadly speaking, the greater the amount of mixing the better will be the product, and as, by their construction, mixing machines cannot easily be overloaded, they form admirable appliances for securing a regular supply of material to grinding pans, which are troublesome if supplied irregularly. It is when used for this purpose that they are termed "feeders". In the United States the term "granulator" is identical with the British "mixer". A special class of feeding machines which do not mix the material will be described later (p. 182).

Mixers are distinguished from pug-mills for convenience; in reality pug-mills are only a form of "mixer," though this latter term is commonly understood to refer to machines of the open trough type. They are generally made of iron or steel with one or more long shafts running through the centre, to which are attached knives which thoroughly mix the clay before it enters the pug-mill. In some cases the knives of the pug-mill and of the mixer are both on one shaft, but it is more usual to have

separate mixers which mix the clay and water together and then discharge the paste into the pug-mill.

Mixers are generally placed just below the crushing rolls, and sometimes other pairs of rolls are placed underneath them for a final crushing before the clay enters the pug-mill. The value and efficiency of a mixer must be judged by the extent to which it converts the materials supplied to it into an even paste, but no accurate conclusion can be reached unless it is first clearly shown that the material is in a suitable condition to be mixed. No mixer can be really effective unless the material supplied to it is free from large pieces of hard material, though several strong knives in a long mixer will often effect a remarkable degree of homogenization.

The best test of a mixer is to take small samples from different portions of the paste which issues from the machine, and to examine them carefully by the eye and also by a simple sifting test after stirring them up with water. When clay of a tough, stony nature is used it will frequently be found advisable to employ a powerful mixer to "granulate" it before passing it to the crushing rollers. This custom is very common abroad when highly plastic clays are being treated, the argument in favour of this arrangement being that it is said to require less power than the use of spiked or kibbler rolls.

The supply of material in a constant regular stream to the various machines is so important that it should receive far more consideration than it has, hitherto, done from many brickmakers; the employment of a simple mixer or feeder will often go far towards solving the problem of "wasted engine power".

The essential parts of a clay mixer are a case or shell of ample strength, the shaft or shafts carrying the mixing knives, a supply of water capable of being accurately regulated so as to produce a paste of the required consistency, and the gearing necessary for the transmission of power to the machine. These parts should all be exceedingly strong and well fitted.

Clay mixers may have a single shaft to which the knives are attached, or two or more such shafts may be used. For most purposes two shafts placed parallel to each other form the most efficient mixer.

Single shaft mixers form efficient conveyers for short distances. The blades should be very strong, preferably of steel, and should be fitted so that they work at a suitable angle to the shaft and to each other. This angle can only be found by experimenting

with the clay to be used, and it is not uncommon to find that a mixer can be greatly improved in efficiency if the shape, size, spacing, and angle of the blades are altered. These changes should not be made, however, without expert advice of an impartial character.

In double shafted mixers the blades or knives should revolve in opposite directions and at somewhat different speeds (preferably in the ratio 1 : 2), as this enables them to break up and reduce the material more readily and to mix it better with the water. The materials, and as much water as is thought necessary, are fed in at one end of the mixer, and leave in the form of a more or less plastic paste at the other.

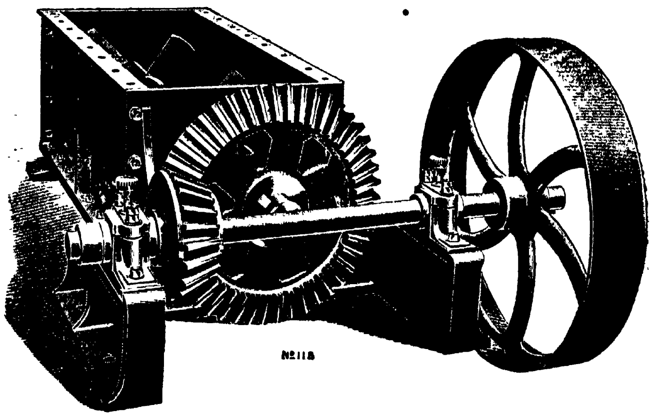

FIG. 62.—Single shaft mixer.

It is a curious fact that, although mixers are sold by all makers of general brickmaking machinery, there are very few really good machines for this purpose on the market. In most of them the blades are too narrow or too fragile, and are made of unsuitable metal, so that they are weakest in the most important part. This is especially true of the single shaft mixers, though the ones shown in figs. 62 and 63 are notable exceptions.

The bearings in most mixers are of good design, but in many cases are too small to take effectually the sudden strains often placed on the machine. In all clay-working plants it is essential that the bearings shall be large, of good design, and of suitable metal. They should, preferably, be able to work efficiently in dusty places.

Mixers with double shafts are much more efficient, as they only require one or two additional horse power to the single shaft machines, and the material is more than twice as thoroughly worked. They are, therefore, more popular and are correspondingly better in design, so that little or no difficulty should be experienced in selecting a suitable machine of the double shaft type (figs. 64 and 65).

The blades on one shaft of a mixer of this pattern should work close to those on the other shaft but should not actually touch. They should be strong, well shaped, so as to turn over a considerable amount of clay at a time, and should be set at an angle so as to carry the clay slowly forward. The blades should also be readily replaceable in case of wear or breakage, and should

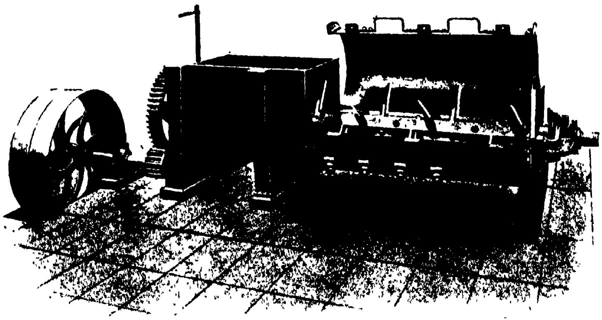

FIG. 63.—German single-shaft mixer.

be secured in position by the use of square or hexagonal shafts and of similarly shaped openings in the farther ends of the blades. This is far more satisfactory than the older plan of fastening the blades with a bolt or nut. Large bosses on the blades make a convenient means of fitting them to the shaft and also occupy space which would, otherwise, be injuriously taken up by clay. The blades may have an elliptical rectangular or triangular cross section, the first-named being, usually, the best. Cast-steel blades are the most serviceable, but no blades should be used when much worn. When in position the blades usually form parts of a screw-thread or worm so as to exert a propelling action on the clay and carry it forward. It is seldom advisable that the blades should *exactly* correspond to this "worm" shape, as slight variations from it often produce a better mixture, but these variations must not be too great.

The number of blades must vary with the clay to be treated, but if four blades constitute one "turn," good results can usually be obtained. The distance of the blades from each other should not be too great, and should seldom exceed 14 in. between two blades on the corresponding positions on the shaft.

FIG. 64.—Double shafted mixer.

In the United States considerable success has attended the use of shafts one above the other instead of side by side as is the custom here. Fig. 66 shows one of these machines which has combined the features of the double shaft mill for mixing different material with the long enclosed case containing a single shaft only for pugging clays. Immediately over the main pug-shaft and extending for about one half of the length of the pug-chamber is an independent mixing shaft containing four rows of steel bars, so located that they just clear the tempering knives in the main shaft. The distance between the two shafts only slightly exceeds the length

of the knives. The operation of these two knives on the material, with the close passage of the knives to each other, secures a thorough mixture of different ingredients before reaching that part of the chamber in which the pugging is completed. Some other mixers are illustrated later (p. 227).

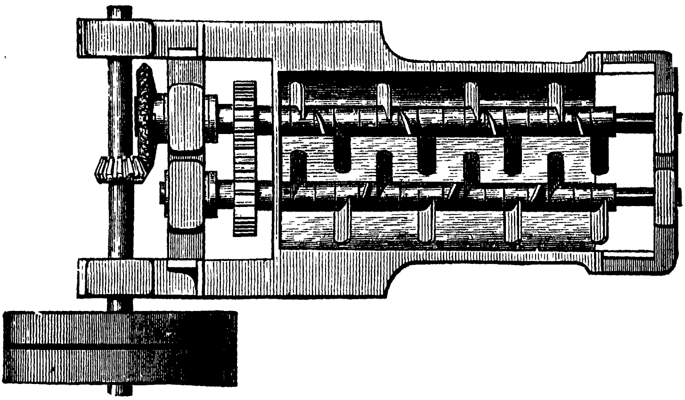

FIG. 65.—Plan of mixer (Bennett & Sayer).

PUG-MILLS, MOUTHPIECE-PRESSES, AND AUGER MACHINES.

The final machine employed for the preparation of the paste for the manufacture of wire-cut bricks by the plastic process is a pug-mill, to the exit end of which is attached a mouthpiece or die which gives the brick its shape. In a few cases this is all the machinery that is required, but with most clays some crushing or other preliminary treatment is necessary.

Pug-mills are also used without mouthpieces, in order to secure a plastic paste of regular composition and of suitable stiffness for further work. In all these cases the same principle is used, though the mill must be more strongly built if a very stiff paste is to be worked than if a soft paste is desired.

At most works making plastic, wire-cut bricks the clay passes through crushing rolls, sometimes through a pan-mill or a mixer or both, and finally goes into a pug-mill where it is thoroughly pugged and mixed under pressure, and eventually shoved out of a die in the exact shape of a column of bricks, and from thence on to a cutting table where it is cut up into bricks.

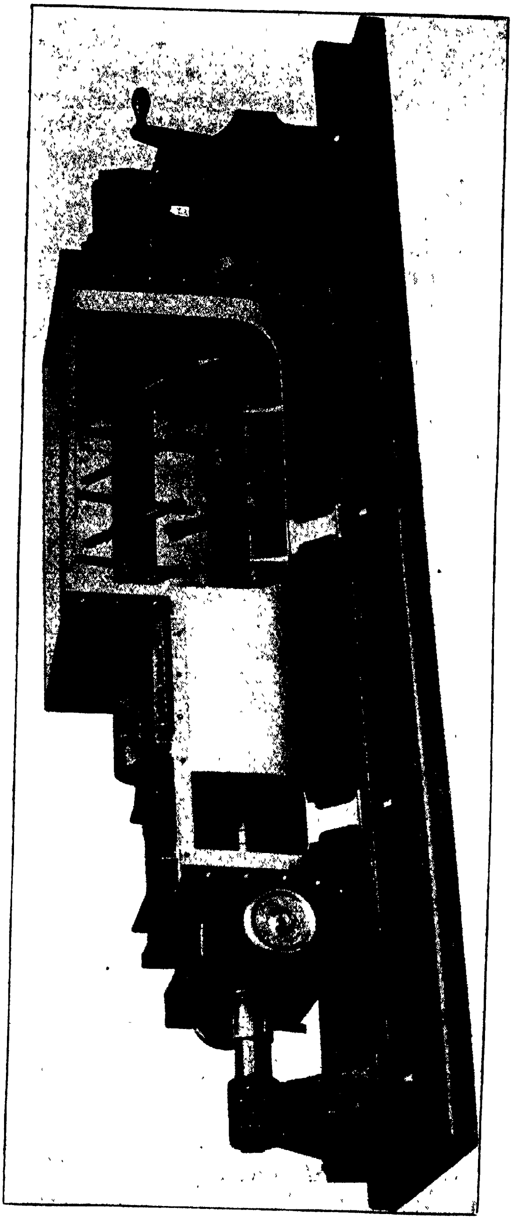

Fig. 66.—American Double-shaft mixer.

A pug-mill is essentially a closed mixer and is constructed on the same general principles as the mixers already described, except that instead of being trough shaped, it is usually cylindrical and slightly smaller at the exit end than at the other. Owing to its shape the clay paste in a pug-mill becomes much compressed and this sets up a resistance, or back-thrust, necessitating powerful construction and great care in design.

In an open mixer the clay falls through an opening in the bottom of the trough at the exit end, but in a pug-mill the clay passes out at the end of the machine. For this reason special arrangements have to be made for supporting the knife-carrying shaft at this end of the mill, and not a few failures in clay-working are traceable to faulty construction in this part of the machine.

Pug-mills may be made with the barrel vertical or horizontal. The former are used when preparing paste for hand-made bricks (Chapter III) and for fire-clay, the latter for nearly all cases where wire-cut goods are to be produced. As it is closed it is impossible to see what is going on inside a pug-mill, and much attention must therefore be paid to the clay which issues from it.

As in open mixers, the blades in a pug-mill are arranged in the form of a screw-thread or worm, fixed projections or blades being sometimes cast on to the inside of the barrel in order to prevent the rotation of the clay. The mill will deliver a more satisfactory column if the end of the shaft carrying the knives is made of corkscrew pattern so as to act as a propeller (fig. 67). It clears a way for the clay behind it and causes a solid column of clay to exude from the die without creating unnecessary back-pressure on the blades of the pug-mill. This is equally true of both vertical and horizontal mills. Valuable as is this arrangement, but few pug-mills contain it, and many are so constructed that it cannot be fitted to them.

In selecting a pug-mill it is essential to have clearly in mind the purposes for which it is to be used. If it is only required for mixing clay with water into a homogeneous paste the blades should be set fairly flat, i.e. almost at right angles to the shaft, and should be broad and numerous. In short, a pug-mill for this purpose should have all the characteristics of a mixing machine. If, on the contrary, the main purpose of the pug-mill is to convert a plastic paste into a band of clay of definite width and depth by forcing the paste through a die or mouthpiece, the

blades should be at a distinct angle to the shaft and should form a screw conveyer of which the thread is broken by the spaces between the blades. These latter should be very broad. Such a mill will press the clay into shape satisfactorily, provided that it be supplied with a properly prepared paste, but will do little or no mixing work.

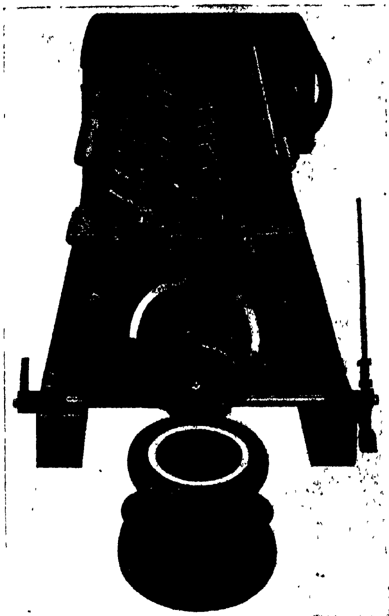

FIG. 67.—Double-shaft mixer (Raymond & Co.).

Intermediate between these types of pug-mill is the one which is most frequently used, and is intended to act as a combined mixing and pressing machine, the clay in it being made by it into a homogeneous paste and afterwards pressed through the mouthpiece to the desired shape. In such a machine the majority of the blades should be arranged for mixing, but those nearer the exit end should be set at a smaller angle so as to be propulsive, and a couple of turns of a complete screw should be provided at the end of the shaft. These precautions are often overlooked, with the result that many troubles arise, particularly if a stiff paste is required.

A pug-mill should work with the least amount of water the required consistency of the mass will allow, and that mill is, broadly speaking, the better which can produce an equally good mixture with less water than another, providing it does not require more driving power. The various parts of the mill must be of ample strength owing to the great compressive forces exerted, and on this account the shaft and blades must be of ample proportions and the thrust bearings well made and kept properly lubricated and covered so as to be free from dust. The blades should not be used when unduly worn.

The speed at which pug-mills are driven is often ridiculously slow; thirty to forty revolutions per minute is good practice, but many English clay-workers drive at half this speed, and thus waste power and produce an inferior result. Much, however, depends on the nature of the clay, and the brickmaker can only ascertain the best driving speed by actual trial.

Many pug-mills are too short, and so fail to mix the clay supplied to them; 6 ft. is seldom too long, and many clays require a preliminary mixing to have taken place before they can be dealt with satisfactorily in a pug-mill of this length. In such cases the mixer is attached to the pug-mill and driven from the same pulley, the mixer being fixed at such a height as will enable the clay from it to fall into the pug-mill.

The construction of the thrust bearing is highly important,

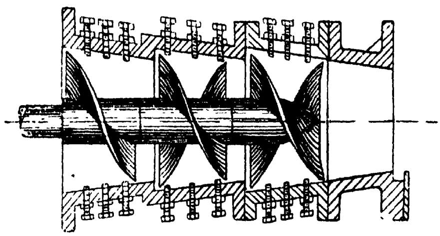

Fig. 68.—Griessmann's pug-mill.

and most of the firms making pug-mills and brick machines have paid special attention to the design of their bearings.

Friction discs are much used, as are also projecting rings on the shaft working in grooves in the bearing (as in marine work).

An ingenious device by F. Lane consists in attaching a hemisphere of hard steel to the end of the shaft, and a similar one in the thrust block. As the shaft rotates its hard rounded end works on the corresponding convex face of the thrust block, and the arc of contact is reduced to a minimum. Whatever type of thrust or journal bearings are used they must be kept clean and well lubricated.

A German patent (fig. 68) by Griessmann, consists essentially of a series of conoids with screws through their sides to prevent the clay rotating, and a series of helicoidal blades to propel it forward. This arrangement has increased the output of some mills not provided with a clearance screw at the end of the shaft by 30 to 40 per cent.

The best shape of the exit end of a pug-mill depends greatly on the mouthpiece. If the latter has a small opening there should be a long conical piece between the end of the mill and the mouthpiece proper. If large articles are being made, this conical piece may be shorter. The most suitable length must be found by experiment.

Mouthpieces.—As a rule only one mouthpiece is used on each machine, but where the clay will permit it there are advantages in using two mouthpieces set at an angle to each other, as in fig. 69.

The designing of a mouthpiece to work with a given machine is one of the most delicate engineering operations connected with brickmaking. Variations of apparently trifling magnitude

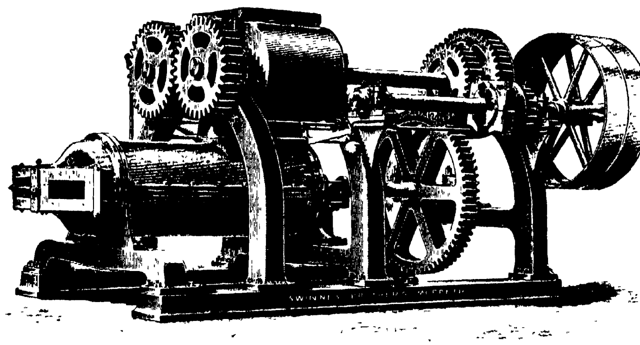

FIG. 69.—Brick machine with double mouthpiece.

cause serious defects, and the alteration of a mouthpiece is a matter requiring careful thought and much experience and skill before it can be done satisfactorily. With plain bricks made from plastic-clay the difficulties are fewer and less troublesome than when hollow goods are produced by the wire-cut process, but in all cases some skill is required, and often much patient experimenting must be carried out before success is gained.

In principle, the mouthpiece is extremely simple, it being merely an opening at the end of a pug-mill. This opening is of such a shape (usually about $9\frac{3}{4}$ in. × $4\frac{5}{8}$ in.) as to produce a column of clay paste the width and length of a "green" brick; and it might be assumed that a plate attached to the exit end of the pug-mill with an opening of the correct size is all that would be required. If a very soft paste is used, and no attempt is made to

keep the clay to a special shape, such an assumption is correct; but as soon as the paste is made stiff enough to retain its shape on leaving the machine, a back-pressure is produced on the machine and troubles begin forthwith. A few tests will soon show that some means for effecting a gradual change in the shape of the clay column is necessary. Inside the mill this column will be a cylinder of 12 to 18 in. diameter; after passing through the mouthpiece it will be a rectangular one of $9\frac{3}{4}$ in. × $4\frac{5}{8}$ in. This reduction of cross-section must be effected so gradually as not to cause avoidable friction in the pug-mill, and for this purpose a conical collar must be placed between the mouthpiece opening and the barrel of the mill, or the latter must be made conical throughout its length. There are reasons, which need not be detailed here, why the latter plan is less desirable than the former, the most important being the end support of the shaft carrying the knives.

As this conical reducing piece is in some ways of greater importance than the opening in the mouthpiece, the two combined may be considered as forming the mouthpiece. The most suitable length for the reducing piece will depend upon (*a*) the relative sizes of the mill-barrel and the mouthpiece opening, and (*b*) the rapidity with which the cross-section of the clay paste can be changed without detriment. Some clays can be worked with a very short mouthpiece, as they can be rapidly changed from one shape to another, but others need very gradual reduction. No general rule can be given, as the length must be found by trial with the clay mixture for which the mouthpiece is to be used. Even then, variations in the stiffness of the paste may prevent well-shaped articles being made. It is seldom that the distance between the end of the cylindrical part of the barrel of the mill and the opening of the mouthpiece can be less than 12 in., and a much greater distance is often required.

With certain clays, a very accurately constructed die, and a suitably sized mill, the reducing piece is unnecessary, and as the output of a mill in which it is not used is increased 19 to 40 per cent, most makers of mills prefer to keep the reducing piece as short as possible. This is quite right providing that it is not overdone, as an unnecessarily lengthy reducing piece or nozzle may yield bricks with weak corners and edges. Too short a nozzle will, on the other hand, give badly shaped bricks with torn edges and will waste power.

As the clay paste on leaving the barrel proper is circular in

section and the final shape of it is rectangular, the internal shape of the reducing piece is often peculiar and difficult to describe. The reduction in cross-section puts a large amount of pressure on the clay—in some cases it is sufficiently great to stop the machine—and even when assisted by a powerful auger the amount of power required is often serious if the reduction takes place in too short a distance.

If a short collar is sufficient, one similar to that shown in fig. 70 may be used, but if a longer one is needed it will be better to introduce a conical casting, similar to that shown in fig. 71.

Between an ordinary mouthpiece and the barrel of the mill, or instead of a perfectly conical casting, a specially shaped reducing piece may be used. If the mouthpiece is sufficiently large no collar is necessary, as the mouthpiece produces the whole of the change from a circular to a rectangular shape.

A third alternative may sometimes be employed, though this is seldom the case, i.e. the barrel of the pug-mill may be of so small a diameter as to need no reducing piece. This has the disadvantage, however, of not mixing the clay so thoroughly as when a larger mill is used.

Instead of the mouthpiece being at the end of the pug-mill it may be at the side (fig. 72), though this, in the author's experience, is less satisfactory with many clays, as the thrust on the solid end is great and the direction of movement of the clay is changed suddenly just before it leaves the mill. At the same time it must be admitted that machines of this pattern are giving satisfactory results in some districts.

The mouthpiece must be made of, or at any rate lined with, hard metal, as the internal wear is very great. It must also be kept accurate or the bricks will vary in size. Ordinarily, fresh liners must be inserted and the old ones "trued up" or discarded; but an ingenious device patented in France by T. Hervé deserves consideration in this country. As will be seen from the illustration (fig. 73) the sides of the box are joined at two opposite corners, and when the box has become too large it is only necessary to remove the bolts (*cc.*) and to pull the two halves of the box asunder along the lines 1 to 2, and 3 to 4. By grinding these angles the four parallel sides of the box can again be brought to their normal size, and the whole, bolted together, is then ready for use. This invention attempts to do away with most of the trouble ordinarily experienced in relining

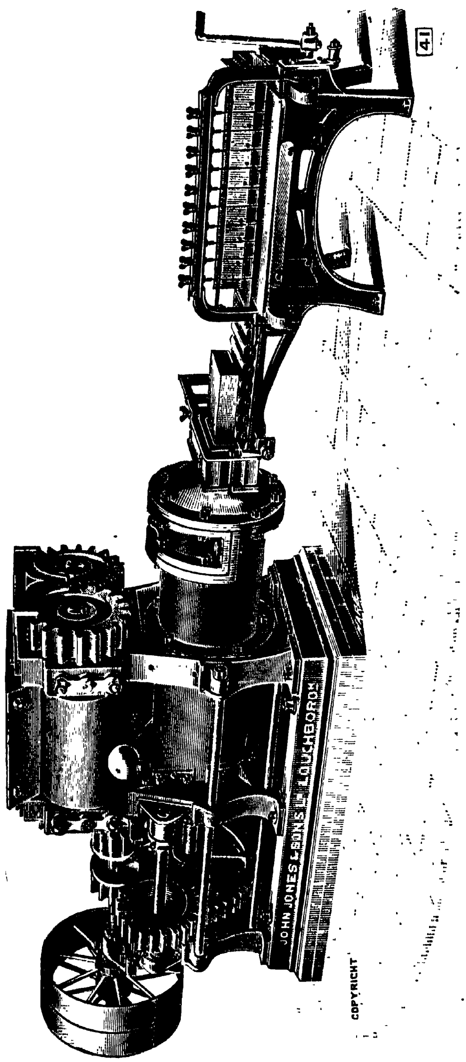

Fig. 70.—Brick machine showing short collar.

ordinary dies, as, provided reasonable care is taken, the sides of the die cannot become untrue during the grinding of the angles.

It is especially important that the mouthpiece should be capable of easy removal from the machine, so that another, with a differently shaped opening, may be substituted or so that the die may be cleaned or repaired. Many machine-makers have paid too little attention to this matter, with the result that the changing of a mouthpiece often requires a couple of hours' hard work by two or three men. Instead of bolting it on with long screws of slow pitch, shorter threads may be used or, pre-

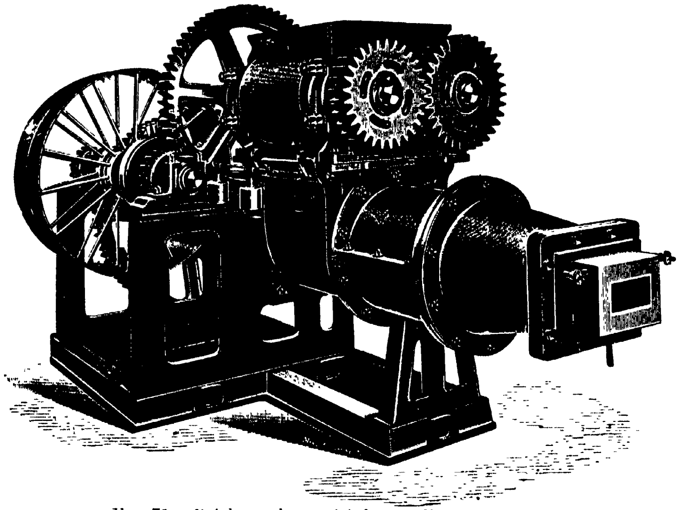

FIG. 71.—Brick machine with long collar (Whittaker).

ferably, instead of being bolted all round, the mouthpiece may be provided with a hinge at one side and a bolt at the other, so that all that is necessary for its removal is the unfastening of the bolt and the drawing out of the hinge-pin (fig. 77*b*). For cleaning the die it is sufficient to unfasten the bolt and turn the mouthpiece on its hinge. If the hinge is made sufficiently strong it will not be bent by the pressure of the clay in the press.

Much trouble is experienced if the clay cannot easily pass through the mouthpiece, and to facilitate its passage the die is usually lubricated with water, steam, or oil. If the clay is fine in texture the die may be lined with copper or brass and water used for lubrication, but with clays containing much hard

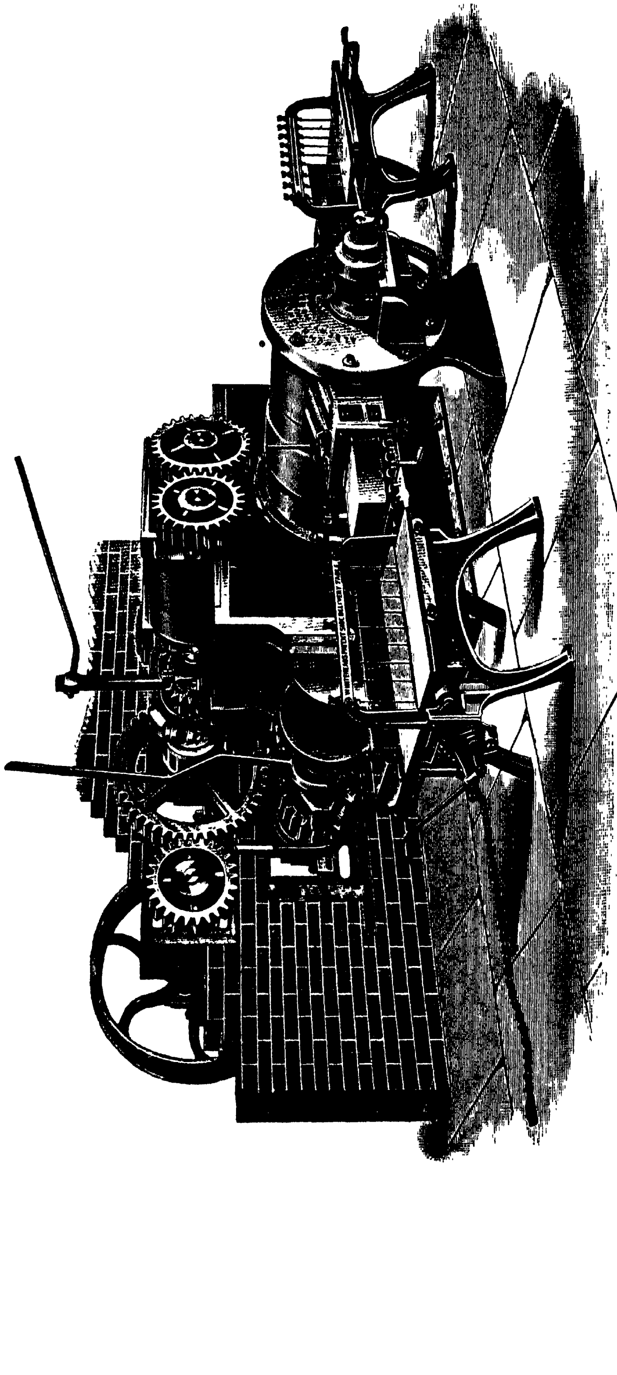

Fig. 72.—Side-delivery brick machine.

material steel-lined dies are better, and oil may be the only suitable lubricant, though water or steam may sometimes be used.

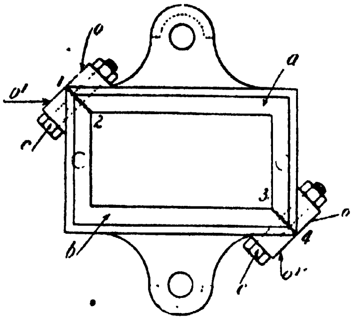

FIG. 73.—Hervé's mouthpiece.

One of the earliest mouthpieces placed on the market was that designed by the late H. Clayton in which two cylinders (fig. 74) formed the sides of the opening. These cylinders were slowly rotated by appropriate gearing mechanism and served to help forward the clay column. It has not been generally adopted.

During recent years it has been found that "lubricated dies" are the most satisfactory, and many patterns of these are now obtainable. They vary in complexity from a straight-edged die lined with copper or fustian to very elaborate arrangements.

A die of modern type, made by James Buchanan & Son, is

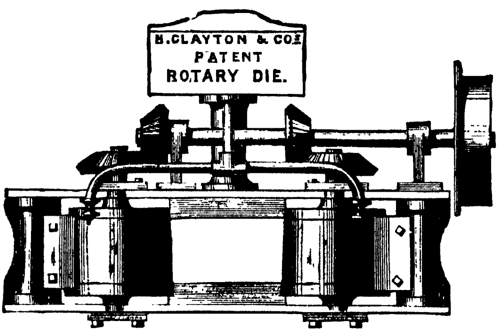

FIG. 74 —Mouthpiece designed by H. Clayton.

shown in fig. 75. This has a double supply of lubricant, so that the corners may be treated separately from the sides of the clay column—an important convenience with some clays.

It is very necessary in constructing a die, to see that the clay column issues at the same speed over the whole cross-section. Unless special care is taken, the centre will travel faster than the sides and far faster than the corners. Should this be the

case, the die must be widened where the clay travels slowest, and so adjusted until an even flow is obtained. Otherwise, the bricks will be defective at the edges and will not be of average

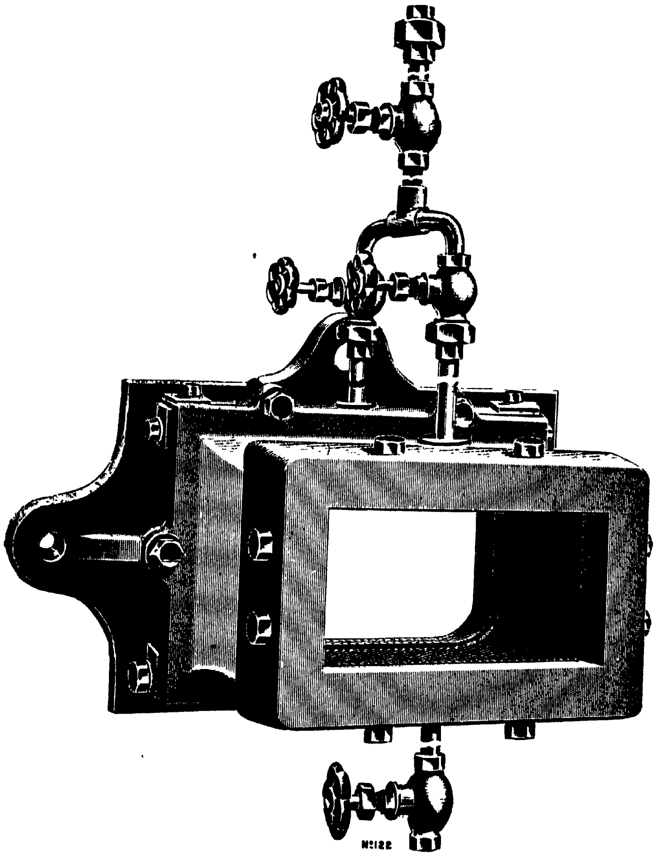

FIG. 75.—Lubricated mouthpiece.

strength; in bad cases, the edges will resemble "crocodiles' teeth" owing to the clay being torn as it comes through the die.

To avoid the time, trouble, and expense connected with working in metal, the author invariably uses wood for experimental dies, and as soon as a reasonably satisfactory result is obtained he has a casting made. When this casting has been altered

until satisfactory, he has a proper die made to the exact shape of the adjusted casting. No other method has been found so convenient as this with really difficult clays. Fortunately, it is seldom necessary to carry out so full a set of tests, as one of the numerous mouthpieces on the market will usually work admirably with all except the most difficult clays.

Whenever possible, water or steam is preferable to oil, not only on account of its cheapness (though the mouthpiece requires more oil than is used to lubricate all the rest of the machinery in the plant), for oil of a cheap grade is used, but because oil enters the surface indentations and corner-cracks and prevents them from healing under later pressure. Steam has the advantage of warming the clay as well as reducing the friction produced in its passage. But little pressure is required on the oil, but with water a pressure corresponding to that of most towns' supply is needed. When all the water used in the works has to be pumped, it may be necessary to use a pressure cylinder. Fig. 76 shows a simple and suitable design in which the upper tank is filled with water and steam is blown in at the top, so as to produce the pressure desired at the mouthpiece.

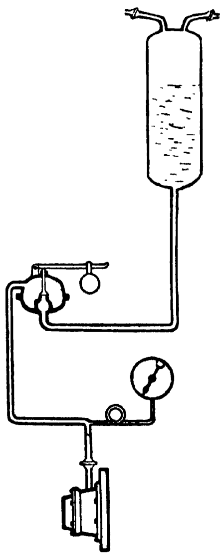

FIG. 76.—Stull's pressure regulator for mouthpiece lubrication.

By sliding the weight to and fro along the regulator-arm, any desired pressure between zero and that of the steam in the boiler may be obtained. This is necessary, as turning a tap on the supply-pipe is often an ineffective means of reducing the pressure, as it cuts off too much of the lubricant. A pressure-gauge, placed as shown in fig. 76, enables the pressure of the water to be accurately regulated: an essential in the manufacture of the best bricks from a difficult clay.

The water, or oil, enters the die and passing between the lining and the clay facilitates the movement of the latter. In many dies it also passes between the various sections or "scales" of the die, so as to come into contact with the clay at several points in the length of the die. In some dies the only outlet for the

lubricant is between the clay and the lining, but others are provided with a tapped drain pipe, which is useful in regulating the pressure of the water or oil.

As the corners of the clay column require more lubrication than the top, bottom, or sides, special arrangements should be made for an ample supply of oil or water where it is most needed, as by cutting the special channels shown in Groke's patent mouthpiece in fig. 77. It is also wise to introduce sufficient oil, steam, or water at the back of the mouthpiece, so that directly the clay enters it may be smeared with the lubricant. If this is done properly little use will be made of the lubricant introduced in the front or centre of the die.

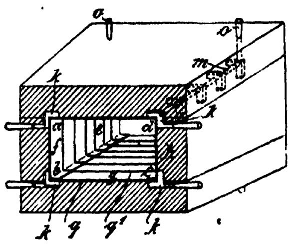

FIG. 77.—Laminated mouthpiece.

The supply of lubricant must be controlled by a tap, and an excess of either oil or water must not be used; the former causes cracks which will not heal, and the latter softens the clay unduly. There is a tendency with plastic clay to allow the paste to become too soft. This is wrong, as for wire-cut bricks the clay should be as stiff as can be obtained without loss in evenness in composition. Indeed, the best results are obtained by working so stiff a paste that many dies will tear it, yet with a properly adjusted die almost perfect bricks can be obtained.

For clays which are difficult to manipulate a mouthpiece with a scale lining is usually the best. Such a lining, as shown in fig. 77, consists of a series of plates, each jointed so as to form a rectangular frame 3 to 4 in. deep. These frames are so placed in the mouthpiece that they overlap considerably and the lubricant, admitted between them and the casing of the mouthpiece, oozes out at the overlapping portion. These laminated plates are made of zinc, tin, or steel, the outer casing being made of wood or cast iron and provided with channels to convey the lubricant to the laminated plates. Some of the most successful water-lubricated mouthpieces of this type used in Great Britain are those patented by Halsband & Co., of Cassel. The laminated linings are easily renewed, but if well made they will serve for the production of half a million to a million bricks (fig. 77a).

R. T. Stull has investigated the structure of laminated and other lined mouthpieces very fully, and has recommended the use of a series of "scales" which touch but do not overlap each other. These scales are in the form of rectangular frames which fit inside the mouthpiece, and are held in position by bolts passing from front to back of the latter. Various modifications of this arrangement are in use by different brickmakers, the object invariably being the production of a homogeneous column of clay, quite free from lamination or other "structure," and

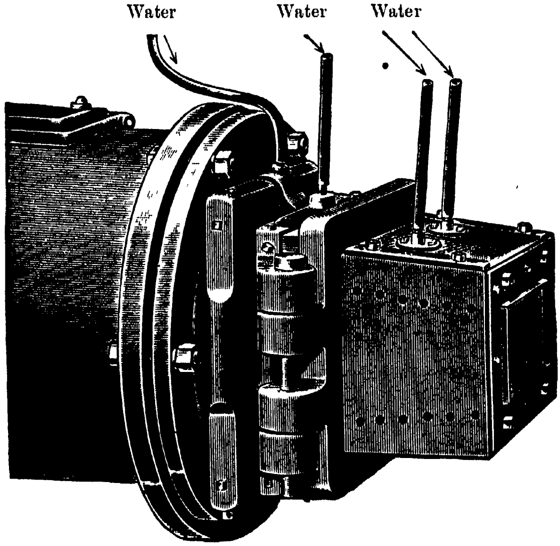

FIG. 77a.—Halsband conoid mouthpiece.

devoid of internal stresses and strains which will later cause the bricks to twist. A perfect clay column can only be obtained by the use of a suitably constructed die, to which the clay is fed by a properly arranged pug-mill or other feeding appliance, the mouthpiece being properly lubricated so that the clay travels at as uniform a speed as possible throughout its whole cross-section.

Sometimes the clay column will expand noticeably after it leaves the mouthpiece or will crack on the face during firing.

In each case the taper of the mouthpiece should then be reduced, either by reducing the size of the aperture next the pug-mill or enlarging the exit of the mouthpiece until the defect is removed.

Properly constructed scale-lined or laminated mouthpieces greatly reduce the amount of power required to drive the machine, as compared to that needed when a fustian-lined die is used, and by adjusting the amount of overlap, the number of plates, the position, size of the channels, and the pressure and quantity of the water, it is not usually difficult to overcome all the ordinary defects in the clay column, and several makers of this type of die are willing to guarantee the production of a perfect band from any kind of clay which can be made into a plastic mass. The exit of the mouthpiece can only be enlarged when the size of the brick is of minor importance.

Most of the defects in the shape of the bricks can be remedied by slight changes in the mouthpiece. If they are hollow on top or side a corresponding opposite curvature should be put in the plate where the hollow occurs. If the bricks after firing are longer on the back than on the face, giving a slightly wedge shape, the liners should be closed in at the bottom, so as to counterbalance this, unless the paste is used in too soft a state. An excessively soft paste causes the clay to "squat" or spread at the bottom and so produces bricks longer on the back face.

It is important to keep the lining frequently renewed and maintained of constant size, as bricks of different sizes are difficult to lay.

EXPRESSION ROLLER MACHINES.

In expression roller machines the die is not fastened on to the end of a pug-mill, but the clay is pushed through the die by a pair of rollers. It is essential that the clay shall be in a perfectly homogeneous condition, as the rollers exert no mixing or crushing action upon the particles.

Express rolls are valuable for making bricks from strong clays in which, owing to great shrinkage, the bricks are liable to twist or crack during the process of drying or burning. Such clay, if of uniform consistence and free from stones, can often be taken direct from the face, water applied to make it of the

proper consistency for plastic bricks and the mixture thoroughly pugged, carried along a copper- or zinc-covered table to the expression rollers, by means of which it is pressed through the die, and will, if proper care be taken, produce a sound brick when burned. With the edges and ends perfectly square, the bricks can be used as "best fronts" with thin joints.

Expression rolls are also suitable for the treatment of clays of a strong tough character, which, when made up with the ordinary pug-mill, have a great tendency to show what is known as "core cracks". The use of a double shafted open pug-mill or mixer in conjunction with expression rollers for feeding the die has been found from long practical experience to be a very effectual method of preventing "core cracks" in bricks, and to produce an article of uniform character and free from lamination.

The dies used with expression rolls are almost identical with the mouthpieces used on pug-mills and described in the foregoing section. Usually they are of rather simpler construction.

A complete machine comprising pug-mill, rolls, die, and cutting table of a type at one time very popular is shown in fig. 78. It is known as the "Murray's patent," has a daily output of 15,000 bricks, and needs about 10 h.p. to drive under good conditions. A similar machine using a horizontal pug-mill instead of a vertical one and provided with hauling gear is made by Swinney Bros., Ltd. (fig. 79). In this machine the rolls are 18 in. diameter by 20 in. long and are grooved. Wootton Bros., Ltd.'s expression rollers figs. 79*a* and 79*b* are 24 in. diameter by 14 in. long, and are mounted on steel shafts carried in long cast-iron frames with renewable side cheeks, which can be adjusted to compensate for wear, the top roller being also adjustable. A rocking feeder is fitted to the machine to compress the clay up to the rollers. This is worked by an eccentric on one of the driving shafts.

This machine is powerfully geared, and driven by fast and loose belt pulleys or friction clutch, as desired, and is practically self-contained on a massive bed plate. Such a machine is extensively used for making quarries, hip and valley tiles, ridge tiles, and a variety of solid, perforated, and tubular bricks from clays liable to laminate when passed from a pug-mill direct to a die, this defect being prevented if the clay is forced through the die by the rollers instead of by a screw.

FIG. 78.—"Murray" brick machine.

Fig. 80 shows a front view of a similar machine made by T. C. Fawcett, Ltd., which is simple in design, and of great strength. It is self-contained on a strong bed plate requiring

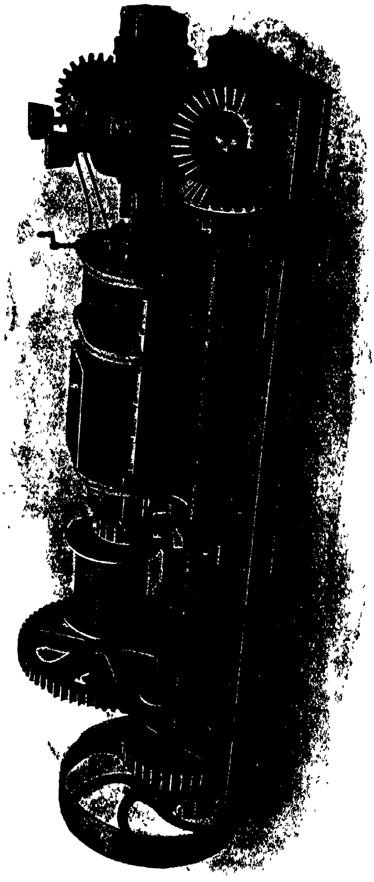

FIG. 79.—Swinney Bros.' expression rolls.

little foundation and no skilled labour to fix. The same firm also make another roller machine in which three pairs of expression rollers are used with correspondingly satisfactory results. In this machine the clay is passed through one pair of expres-

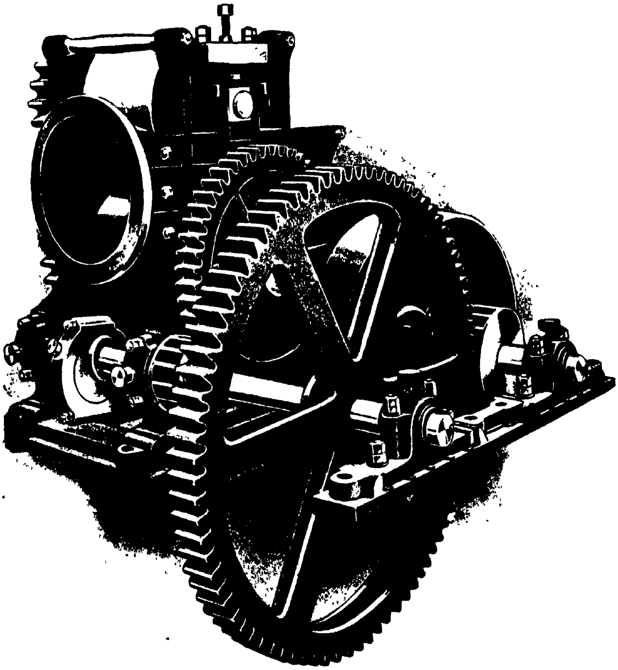

FIG. 79*a*.—Front view of Wootton Bros.' expression rolls.

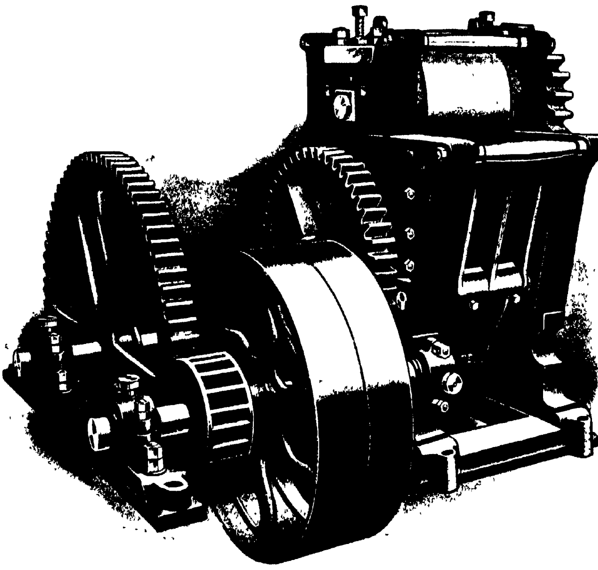

FIG. 79*b*.—Back view of Wootton Bros.' expression rolls.

sion rolls set wide apart, then through a second pair set somewhat closer, and finally through the third pair and the die. Some strong clays which are notoriously difficult to work have been very satisfactorily dealt with by this machine. It must always be remembered that expression rollers are only formative machines, and that to obtain good results with them the clay must have been very thoroughly and carefully prepared. On this account it must have been crushed (if necessary) as well as pugged.

With difficult clays it is often necessary to use extensive pre-

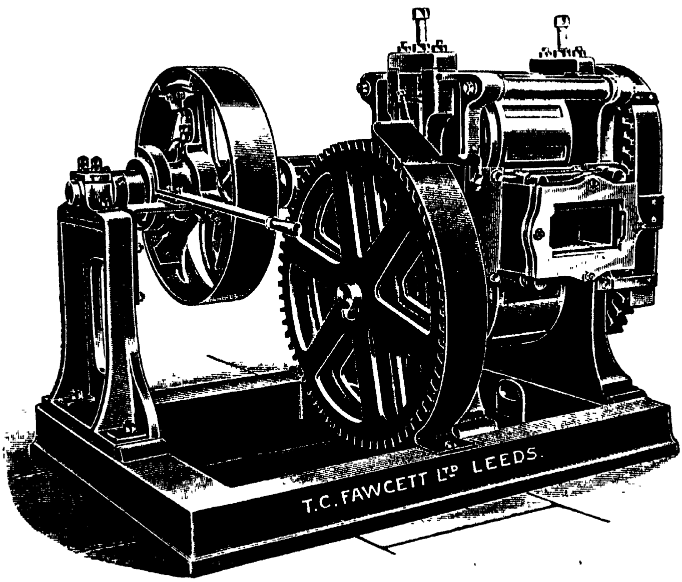

FIG. 80.—Expression rolls and die.

liminary plant, as may be seen from fig. 81, supplied by Wm. Johnson & Sons (Leeds), Ltd., or other arrangements of plants (pp. 77-87) may be used, the expression rolls being inserted between the exit end of the pug-mill and the mouthpiece.

Cutting Tables form the final machines used in the manufacture of wire-cut bricks. They receive the clay in the form of a long strip and cut it transversely into a number of bricks. Usually a piece of clay at each end is not the full size of a brick, this must be returned to the pug-mill.

The essential characteristics of a cutting table are that it

shall cut cleanly and rapidly, and that all the cut pieces shall be of equal size. When these are secured the precise design of

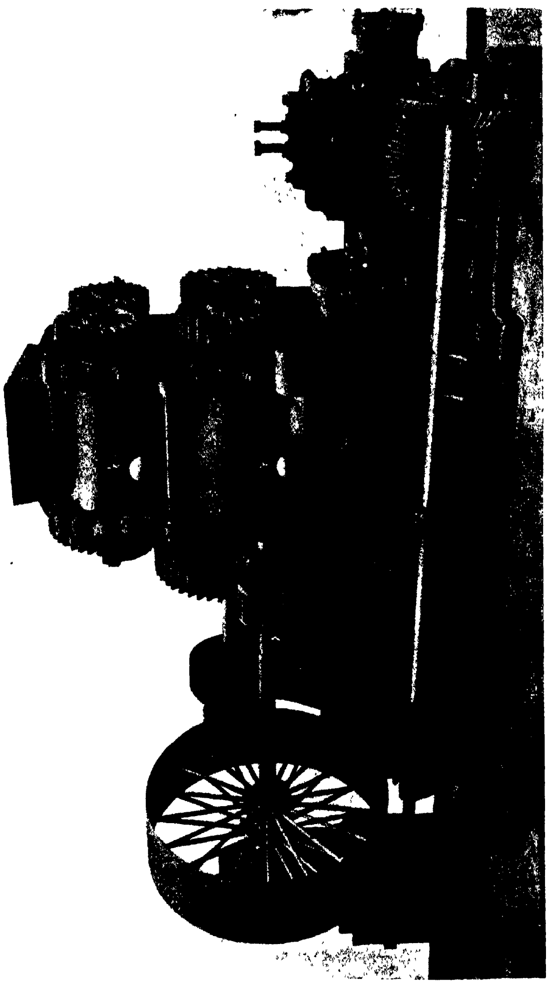

Fig. 81.—Brick machine made by W. Johnson & Sons, Ltd.

the table is of minor importance, and the great variety of patterns now on the market is due to minor variations rather than to fundamental differences in design. In the best cutting tables

the clay is either cut by wires or thin steel blades—the latter giving a somewhat cleaner cut when in perfect condition, but the former are more generally used because they are more easily kept in order, and replaced when broken. Many brickmakers use wires which are too thick to cut properly; it is better to use thinner ones even though they may break more frequently.

One of the simplest forms of cutting table consists of a zinc or copper-covered table smeared with "brick oil," on to which a sufficient length of clay, cut off from the column or clay band, is pushed, and cut into bricks by depressing a frame across which a number of wires are stretched (fig. 82). The frame may then be drawn back or it may be of a rotary pattern and move only in one direction. The cut bricks are then pushed on to a board or pallet and taken to be dried, the pushing being direct by hand or by means of a push board operated by a lever. The disadvantage of drawing back the wires is the production of a rough edge or arris which is avoided when the wire travels only in one direction through the clay. Some brickmakers prefer to have the wires in a fixed frame and to push the clay transversely across them. This method is quite satisfactory where fine clay is used, but for rougher material the downward cut is preferable, as the cut is shorter and leaves the cut edges where they are of less importance in the finished brick.

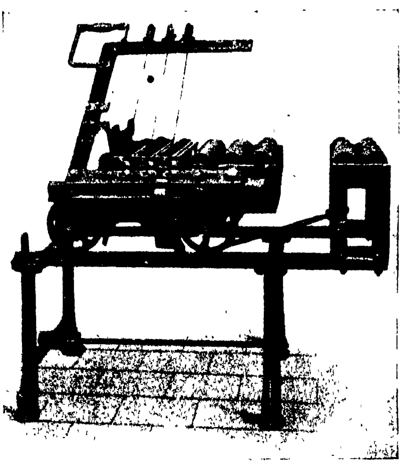

FIG. 82.—Typical German cutting table (Raupach).

Such a table (fig. 83) is manufactured by C. Whittaker & Co., Ltd., in which the clay column issuing from the die of a plastic brickmaking machine is received on the table, being supported by the rollers shown at the left of the illustration. When a sufficient length has passed on to the table the single cutting wire (also at the left side) is drawn across, and the detached por-

tion pushed across by hand, in front of the pusher board. Then by the action of the hand-lever the clay is pressed through the cutting wires and cut into bricks, but these are not delivered on to the pallet until the next lot of bricks pushes them forward, thus preventing the back edges from becoming broken. The bricks thus cut are perfectly true in shape and serious waste is avoided, for by this table the column of clay can be cut off to one inch of the length required for each stroke. The front board or pallet is removed when full of bricks and is replaced by an empty one.

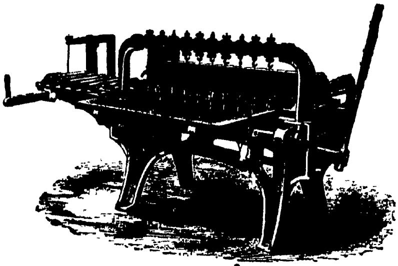

FIG. 83.—Table with fixed wires.

A similar table is manufactured by Wootton Bros. of Coalville, in which, in addition to the usual horizontal rollers, two wooden vertical rollers are also provided to guide the clot on to the table. A large heavy dressing roller is also fitted to run over the bricks after they have passed through the wires. This table (fig. 84) differs from the one just described, in that it is fitted with a two face push-board arrangement and double pallet boards. Sixty thousand bricks per day may be cut on this table.

The "Simplex" brick and tile cutting table made by William Johnson & Sons, Ltd., is different from the two machines described above. The chief feature of this machine (fig. 85) is that the bricks are cut off without the attendant handling the stream of clay in any way whatever. No cross-cut wire is used and all waste ends are avoided, the whole operation being performed by moving a single handle. The column of clay as it issues from the die of the pug-mill is allowed to travel up to the end of the table where a cross-board is fixed. The clay coming in contact with this pushes the top part of the table forward (the table is arranged to travel longitudinally and laterally). The attendant then pulls over the handle (to cut the bricks), draws forward the top of the carriage of the table (to clear the travelling stream of clay), pulls back the handle (to deliver the bricks on the moving board), then pushes the carriage back to receive the column of clay and then repeats these operations.

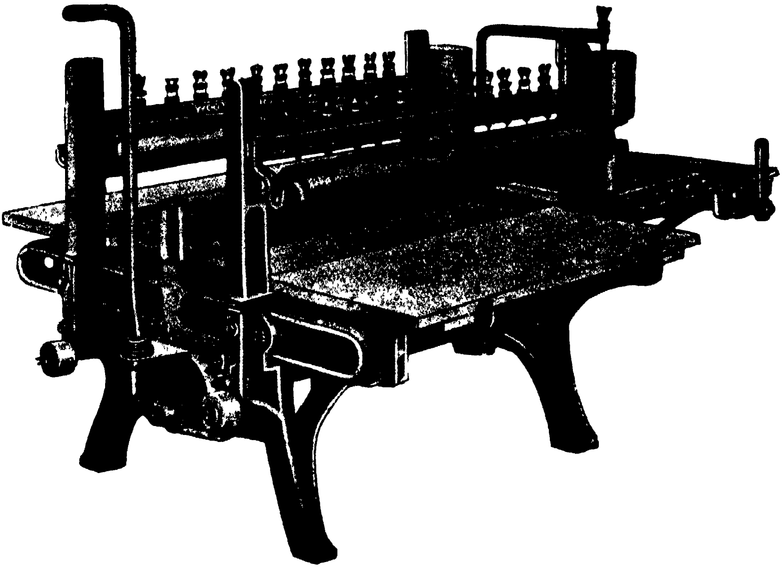

FIG. 84.—Cutting table with dressing roller.

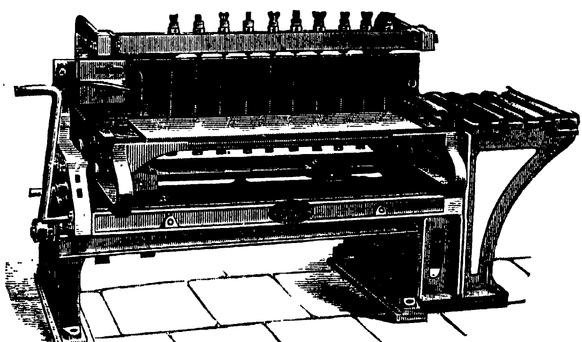

FIG. 85.—"Simplex" cutting table.

In the cutting table made by the Brightside Foundry and Engineering Co., Ltd. (fig. 86), the motion is obtained by a simple lever action, which entirely supersedes the use of racks and pinions. It also has the handle, by which the cutting is performed, placed close to the single cutting wire, so that one man can, without moving his position, perform the various operations of cutting and delivering the bricks on to the barrow, etc. This arrangement renders the work easier and more rapid where the clay is not too stiff.

Following the German custom, John Whitehead & Co., Ltd.,

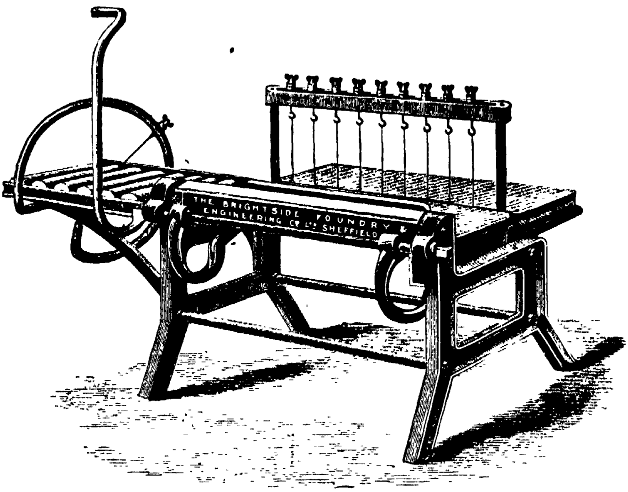

FIG. 86.—Early type of cutting table.

mount the table on wheels which run on a short line of rails (fig. 87), so that when the clay issues from the die of the brickmaking machine it eventually pushes against a vertical stop placed at the front end of the table, thus pushing it along the rails. The clay and table then move at the same speed, and the stream of clay is divided squarely across by the single cutting wire at the rear of the table into the length required to produce a certain number of bricks, usually six or eight. This cut is effected by moving a small lever at the front of the table. The attendant next pulls the table towards him and cuts the separated block of clay into bricks in the usual manner, a side delivery action deposits them on boards, upon which they are

transferred to the barrows, or to the repress, without being handled. The table is then pushed back and the operations repeated.

The table is easily worked by one lad, and can be applied to any ordinary end-delivery machine which delivers its clay in a horizontal stream; the labour and time hitherto employed by pushing the block of clay by hand in front of the fixed cutting wires are abolished.

The machine shown in fig. 87 differs from the tables generally used in Germany, as in the latter the frame moves, making a

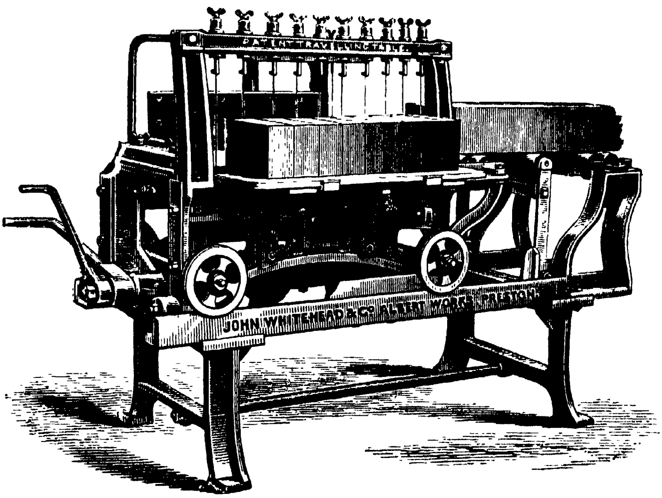

FIG. 87.—Cutting table on wheels.

downward cut (fig. 82) instead of the bricks being pushed through fixed wires. In the Batley cutting table (made by Oxley Bros., Ltd.) the clay band is cut by eight discs of steel instead of by wires. A view of one of these cutting discs, with the band in position ready to be cut, is shown in fig. 88. Each disc is pierced with five circular holes, for the clay band to go through, and when thrown into gear each disc makes a stroke of one fifth its diameter, and cuts off the clay, the pug-mill being stopped temporarily whilst this is being done.

Power-driven tables are slowly increasing in use, though their advantages are not as great as is sometimes supposed.

In Fawcett's patent power cutting table (fig. 89), as soon as the end of the clay column comes in contact with a "stop," it moves it and starts the machine, which automatically stops as soon as the bricks are cut and delivered ready to be taken away. The bricks are automatically separated after cutting so that they are the correct distance from each other (½ in.) when placed on the cars. For successful working, the clay column must be sufficiently stiff not to bend when pressing against the "stop" which starts the machine. The releasing lever must also be kept in good order so that it will operate directly there is a slight pressure on the stop.

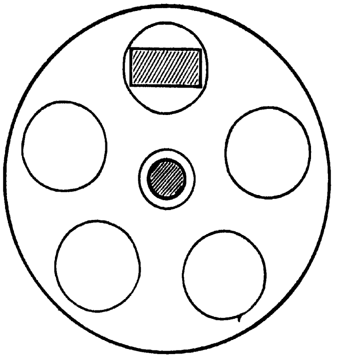

FIG. 88.—Batley cutting disc.

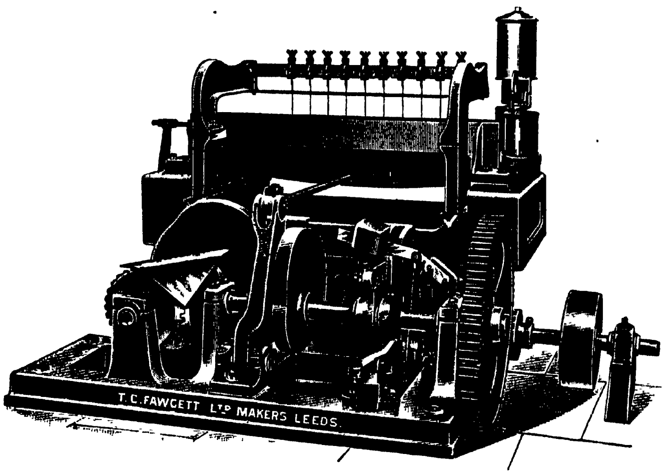

FIG. 89.—Power-driven cutting table.

An automatic cutting table which is set in motion by an electric contact-maker has been successfully used by the author for clays which bend under the pressure needed to start an ordinary releasing lever.

Rotary cutters are much used in the United States but are not employed in Great Britain, with the exception of the Batley cutter just mentioned.

It is a common practice in the United States to cut bricks "endwise," but this practice has never become popular in this country. It is claimed that the defects incidental to cutting are minimized when the bricks are cut across the ends instead of sideways, but this gain is trifling with British clays, and it is more than counterbalanced by the loss due to diminished output.

In order to cut bricks by wires successfully, several details require careful and constant attention; the most important are noted here:—

(*a*) The level top of the cutting table must not be higher than the bottom of the inside of the mouthpiece, nor should it be appreciably lower. In most cases the table is stationary and can be packed up with wood, but where a neater job is required an adjustable stand or table should be used, and is, indeed, essential if large blocks are made by the same process as the bricks. Such an adjustable stand is shown in fig. 90, the legs being lengthened or shortened by rotating them. Another form of adjustment is shown in fig. 91, where the upper portions of the table are moved, the lower ones remaining stationary.

(*b*) The wires must be stretched tightly and must be kept clean. They must also be sufficiently thin to give a good clean brick. German piano-wire is the most suitable for the purpose, and brickmakers should experiment to find which thickness gives the best result. On the Continent, where the clay is ground finer than in many works here, extremely thin wires are successfully used, and the downward cut is invariably employed. In most British yards the wires are too thick to give a perfectly clean cut.

(*c*) The means used for attaching the wires must be simple, strong, and adjustable. Usually a hook below the table receives the lower end of the wire, and a butterfly-nut and bolt working through the frame receives the upper end. Strong spiral springs are frequently inserted between the nut and framework to absorb vibration.

(*d*) In order to make a perfectly straight and uniform cut, it is necessary to have the cutting table constructed with as much care as a high-class lathe. It should be carefully machined and put together, and should have bushings and liners for all wearing parts so that the slightest play may be taken up at will.

This arrangement works fairly satisfactorily, particularly if the lower end of the top bolt is made into a hook instead of being bored, as is usual. It is then possible to keep wires in stock which

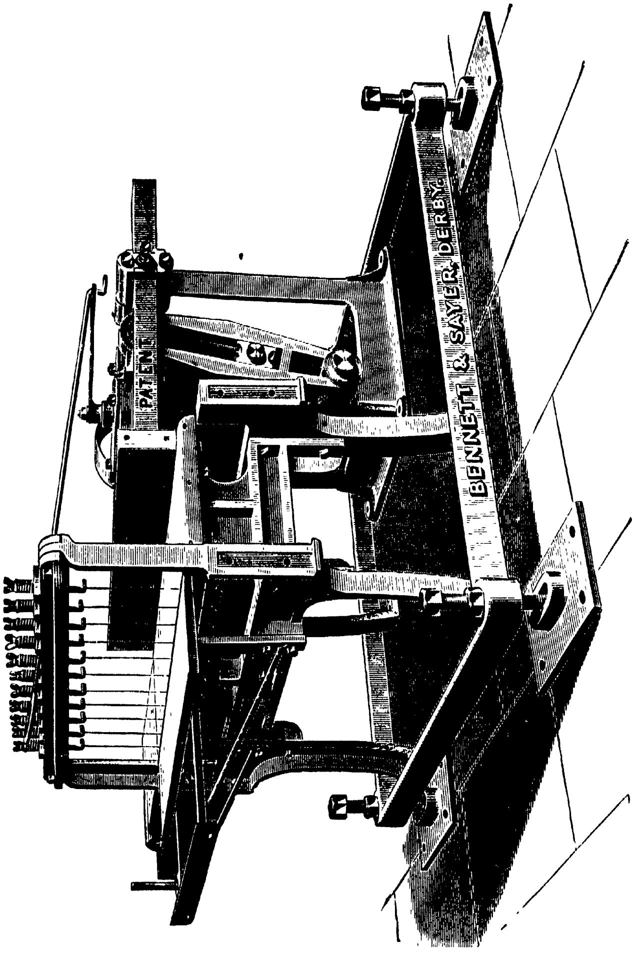

FIG. 90.—Table with adjustable legs.

are cut to the correct length and have a small loop (fig. 92) at each end. To replace a broken wire all that is necessary is to slacken the butterfly-nut, unhook the broken wire, replace it by a new one which has been previously prepared, and again tighten

the nut. This is far better than the plan, often adopted, of threading the wire through a hole and twisting it into a rough loop, as such loops are seldom sufficiently rounded, and the strain being unevenly distributed the wires break too frequently.

A series of keys similar to those used in pianos may also be employed, but it is not easy to make such rapid renewals, and the absence of a spiral spring is a disadvantage with rough clays.

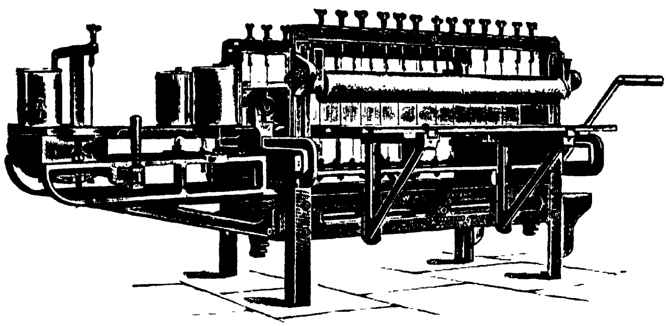

FIG. 91.—Cutter with adjustable table.

Various special attachments and "wire-savers" have been placed on the market from time to time, but the value of these the brickmaker must judge for himself. The author has tried most of them with indifferent results.

If bricks of different sizes are to be made, a cutting table in which the wires can be moved closer together or farther apart should be used, or preferably one to which an additional number

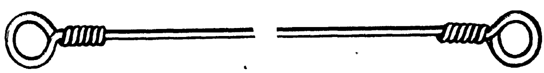

FIG. 92.—Cutting wire.

of wire holders can be attached. This latter arrangement avoids the necessity of readjusting the holders each time the machine is used. If the holders are properly constructed it is a simple matter to remove those wires which are not required, but it is often difficult to adjust the holders with sufficient accuracy when once they have been moved from their place. Besides, the capital tied up by the use of a few extra holders is too trifling to require consideration.

Repressing.—The methods of brickmaking already described are

not often suitable for the production of bricks for facing purposes, as the bricks are seldom sufficiently accurate in form; it is, therefore, necessary to repress them when best facing bricks are required. Before this can be done to advantage it is necessary to dry the bricks until they are black-hard, or leather-hard. They must not be allowed to become too dry or the repressing will not be effective, neither must they be pressed whilst too wet or they will not leave the die properly. Some little skill is required to know the precise moment when a brick is ready for repressing, but it is not difficult to learn this with a little practice.

The presses used for giving bricks an accurate shape are of the screw-press, toggle-lever, and hand-lever patterns, and are driven by hand or steam power. The hand-driven patterns are usually convenient where a portable press is an advantage, otherwise a power-driven press is better. The hand-lever presses are described on p. 60 in the section on Hand-made Bricks.

Screw Presses are a special form of plunger press in which the die-box is carried on a bed-plate or table, and the plunger or male die is forced into contact with it by means of a quick-acting screw, working in a bridge above. The bottom of the die is made loose and rises with the plunger.

The plunger is raised to its full height and simultaneously the bottom of the die is raised to near the top of the box. A brick is then placed on the latter and the plunger lowered by turning the wheel or arms at the top of the press. The speed of descent increases rapidly, and after the plunger has come once into contact with the brick and the force of rebound has started it on an upward journey, the man in charge of the press pulls it down again smartly so as to give a second pressure to the brick. When a power-driven press is used this second pressure is not given, but the single pressure is greater than in a hand-press. There are reasons for believing that two lesser pressures are better than a single more powerful one, and partly on this account power-driven screw-presses have not, up to the present, displaced many hand-driven ones.

Screw presses are made by most manufacturers of brickmaking machinery, but resemble each other so closely that very few examples suffice to show the essential details of their construction. Those of the older type are provided with a long arm (fig. 93) with a heavy ball at each end, but the more modern presses have a heavy wheel (fig. 94) which is steadier and gives a better pressure. The earlier and smaller screw presses were mounted

on wheels for portability, but the later ones are usually of heavier construction and are necessarily fixtures.

The great desideratum in a screw press is the rapidity and

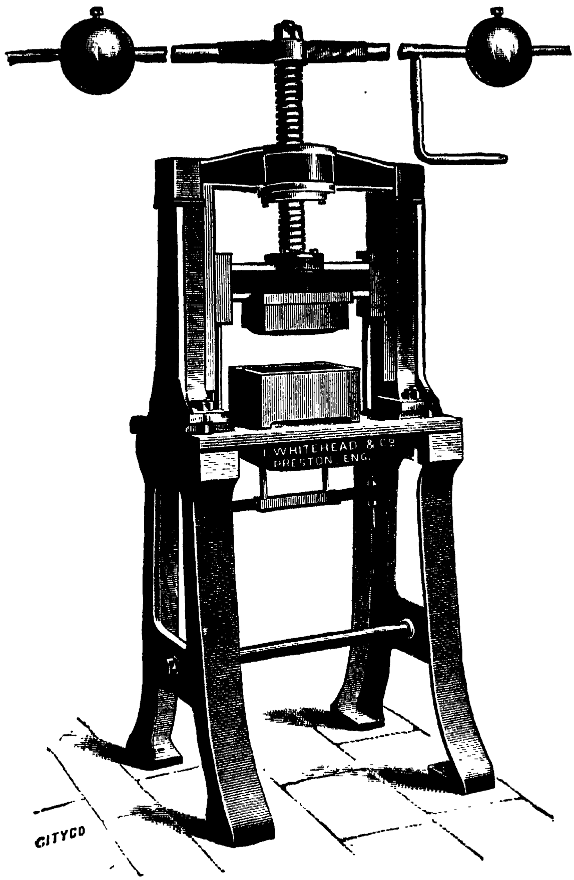

FIG. 93.—Screw press with ball weights.

steadiness of action. Both these are secured to an ample extent in the press shown in fig. 94, as the double action steel screw with right and left hand thread gives a traverse double that of the ordinary screw, and the adjustable arms on each side of the plunger make it impossible for it to shift sideways during its

descent. In this way the damage done by the plunger not exactly entering the die-box is avoided. A man and a lad can press from 3000 to 4000 per day with this machine.

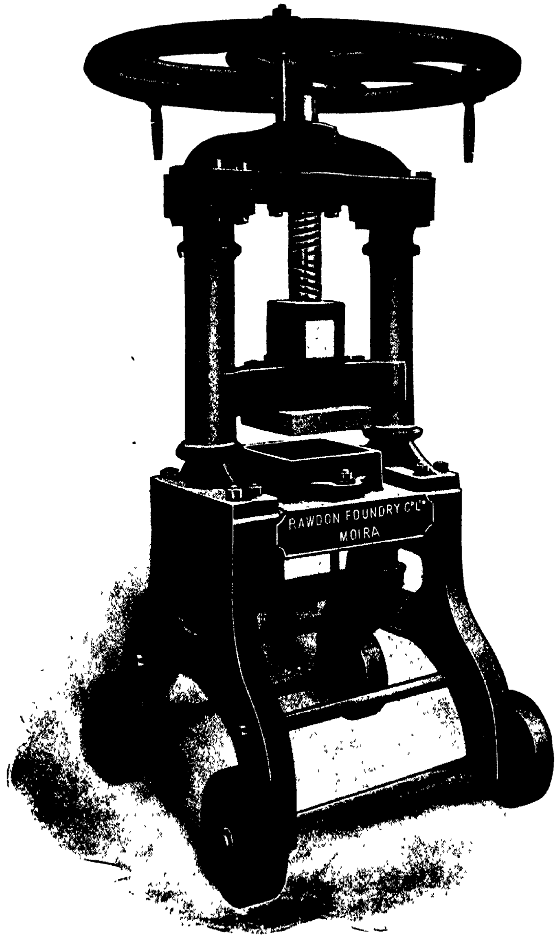

FIG. 94.—Portable screw press.

Power-driven presses of the screw, or Titley type, are largely used on account of the greater output and more uniform pressure. They are similar to the hand-driven ones, but two boys can re-

place the man and lad, as the greater strength of the latter is not needed. Fig. 95 shows a very good means of applying the

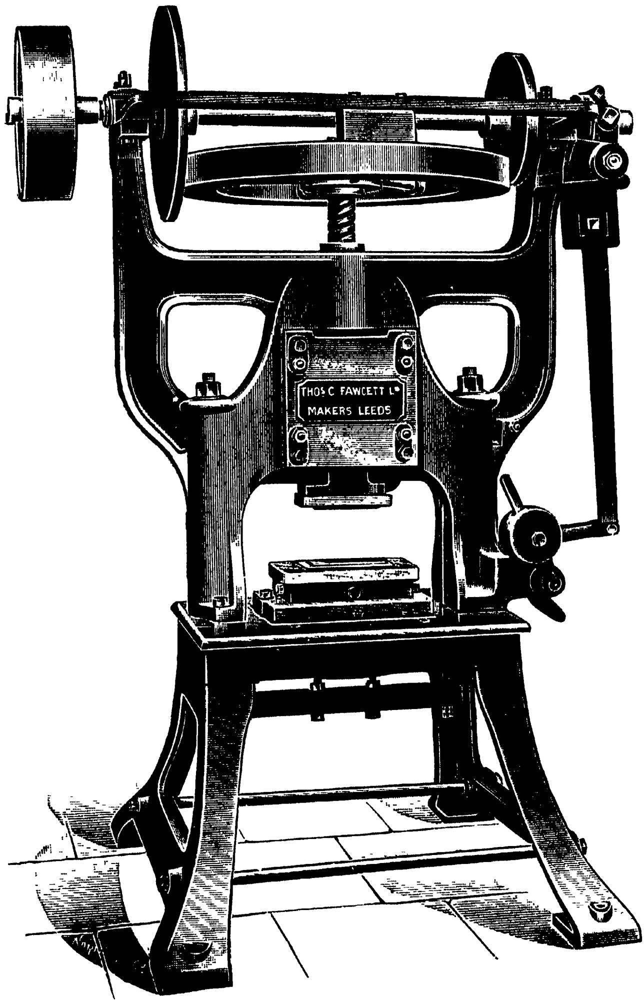

FIG. 95.—Power-driven screw press.

power, viz. by means of two discs which force the fly-wheel round by friction, the one shown in fig. 96 with three pulleys

and crown and pinion driving gear being quite as satisfactory. The power gear starts and stops the press, the momentum of the fly-wheel striking the blow as in a hand-driven press; and an automatic reversing motion returns the wheel to its starting point.

The Pullan & Mann machine (fig. 96) has an advantage in that it can be fitted with the maker's patent measuring appliance which ensures each brick being the same size, any inequalities being shown in the varying depth of the frog.

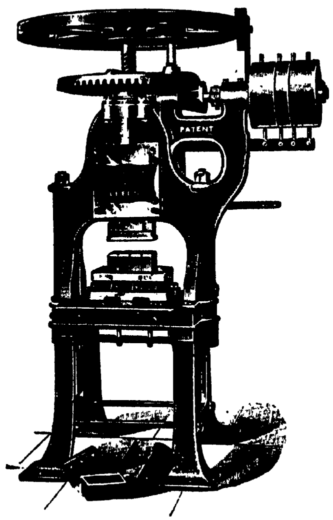

FIG. 96.—Power-driven screw press.

In selecting a screw press, care should also be taken to ensure a simple yet effective means being provided for holding the die-box and for setting it accurately in position. Slotted flanges on the box into which fit strong bolts passing through the bed are, probably, the best form of fastening if the bolts are sufficiently large.

With a machine subject to such sudden strains as a screw press, the bearings need to be specially well made and to be examined occasionally to see that they are in order. If a press of this type "runs hard" the bearings should be examined immediately.

Eccentric Represses, working with a plunger driven by an eccentric motion, are simple in action and have few parts to get out of order. They are preferably made double, so that there is less liability to shock when pressing is overcome, and the pressure is maintained during a longer time. Such a machine is clearly shown in fig. 97, worked by a single cylinder engine attached to it. A front view of a similar press made by Bradley & Craven (Wakefield) is shown in fig. 98, but in this the bricks are placed in and taken off by hand instead of automatically, though a push gear can be added if desired. The press should, as in this case, stop automatically after each brick is pressed, so as to prevent any risk of danger to the attendant.

The essential parts of the machine should be very strong and large; the eccentric and shaft should be of steel and the die lined with hard metal or steel.

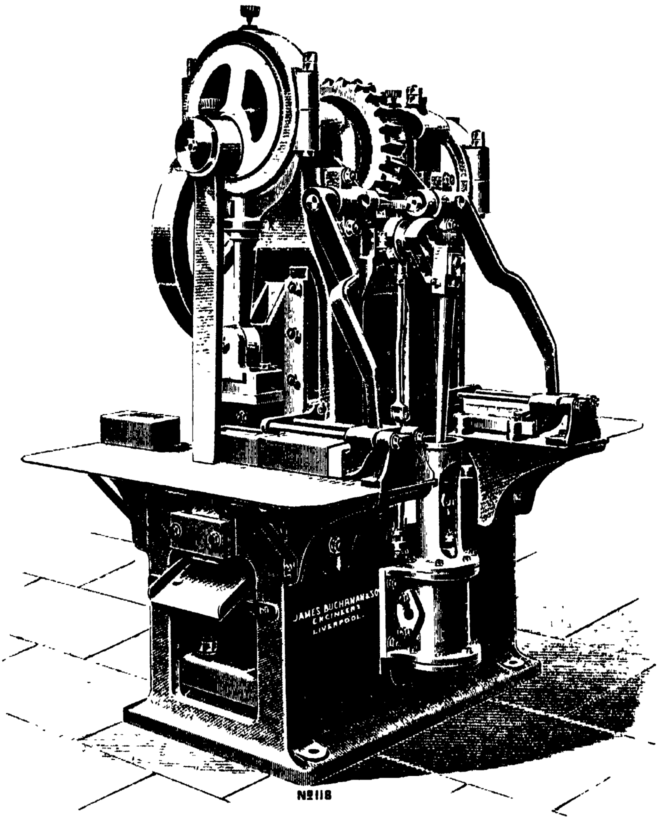

FIG. 97.—Brick press with eccentric action.

The output varies from 5000 to 6000 bricks per day according to the size of the machine.

A good eccentric-motion press of somewhat different type is made by T. C. Fawcett, Ltd. It has been specially designed for repressing wire-cut bricks and has a daily output of 14,000, the bricks being fed automatically or by hand (fig. 97*a*).

Toggle-lever Presses work on an entirely different principle, and give two entirely distinct pressures. Two arms or levers are used, and the pressure is applied in such a manner that after the brick has been pressed by the action of one lever, the motion of the machine brings the second lever into action and a double pressure is thus obtained. Fig. 99 shows a front view of a

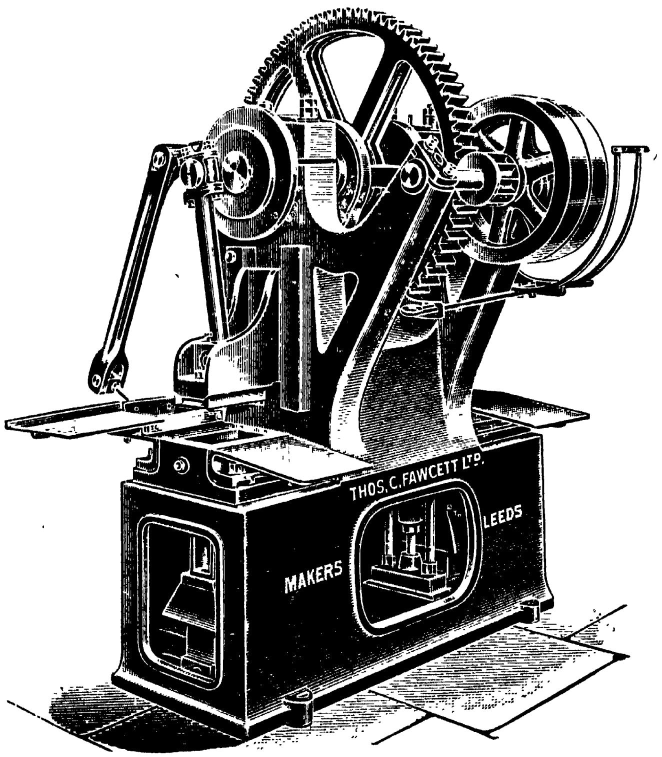

FIG. 97*a*.—Eccentric double press for plastic bricks.

typical press of this type by Sutcliffe, Speakman & Co., Ltd., and fig. 100 a back view of a similar press by the same firm, showing an oil-engine attached for driving it, though a small steam-engine is generally to be preferred. Another important feature of this machine is that the pressure is retained on the brick whilst it is being ejected from the mould, thus rendering it possible to produce bricks with a very good finish.

The motions for feeding and delivering the brick to and from the mould and also for lifting them out of the mould are all self-acting and simple. The bricks can be delivered to either

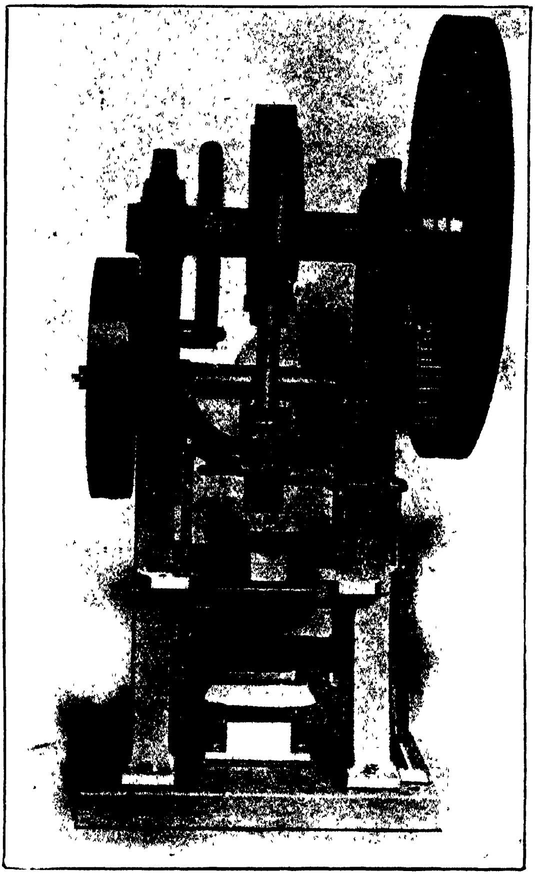

Fig. 98.—Bradley-Craven repress.

side and the press can be easily regulated to press bricks of any thickness.

In all toggle or knee-joint presses it is essential that the pressure should be received where it is needed and not on the

framework, as this type of press is amongst the most powerful used in repressing plastic bricks. The bearings must be of ample size and kept in thorough order and adjustment.

Presses of the toggle-lever type are largely used for the "Semi-

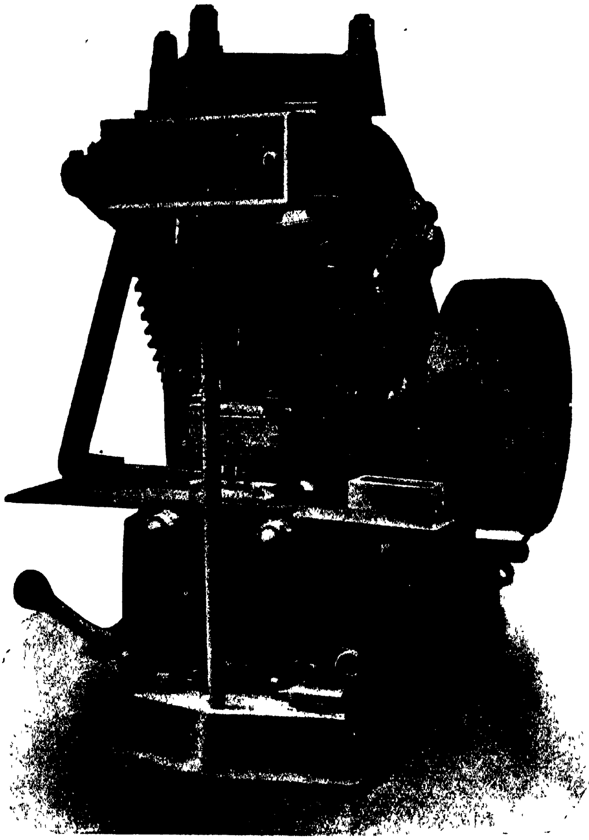

FIG. 99.—Toggle lever press (front view).

dry" and "dry" brickmaking processes, and several other machines will be found described in those sections.

In the use of a press for repressing bricks, numerous little points must be watched if lamination and other troubles are to be avoided. The die itself must be kept true to shape and relined as soon as it becomes appreciably worn, as with a worn die good

bricks cannot be produced. Many brickmakers are careless in this respect and in the accuracy with which moving parts fit into the die-box. Unless these are rightly arranged much power is wasted and the best quality of bricks is never reached. Some

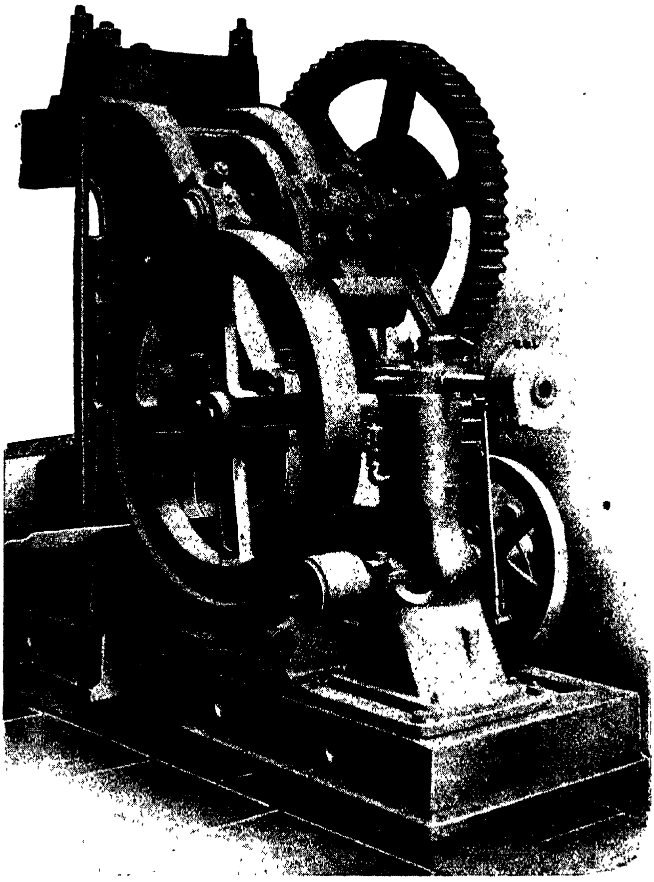

FIG. 100.—Toggle lever press (back view).

firms spoil their bricks with too much oil in the press; others are continually troubled by not using sufficient oil. It is a mistake to suppose that whenever a brick sticks in the die more oil is needed. Sticking is more frequently a sign that the bricks

are pressed in too soft a state, and by leaving them to dry a little more, much sticking may be prevented.

The use of colza or cod oil mixed with paraffin in the proportion of one teaspoonful or more to a pint will often enable better bricks to be produced than when a cheaper lubricant is used on the bricks. Various methods for applying the oil have been suggested from time to time, but none appear to be better than wiping the mould repeatedly with a greasy rag, and occasionally leaving the die full of oil for a night. Most of the trouble of bricks sticking is, as already noted, due to pressing them when too wet.

One common defect is the plunger (or male) die not engaging properly with the box (or female) die, but hitting the edge of the latter and then slipping in. In time, the dies become so worn that an arris, or false edge, is produced on the bricks, and their value is seriously diminished. This can only be avoided by keeping the guides for the plunger and the bearings through which the moving portions work very steady, so as to prevent slipping, and by placing the die-box very accurately in position and clamping or bolting it down whilst the plunger is actually engaged in it.

This matter of accurately fitted dies is more important than appears at first sight, as defects in this part of the machinery not only produce unsightly bricks, but cause so much waste of pressure as, in many cases, to prevent the repressed bricks from being any better for the treatment. This is one reason that so many firms find that repressing adds little or nothing to the strength of the bricks. Effectively performed, repressing is an advantage, but if the process is badly managed it would be better for the bricks had it been omitted.

A brick once formed has a definite "set" or structure, and if it is repressed in a proper manner and at the proper time, the particles will simply be compressed and a denser brick obtained. If, on the contrary, the brick is placed in a die which is too large for it, or into one of a different shape, the "set" of the brick will be destroyed by the extensive movement of the particles under compression, and a complex structure, due partly to the original formation of the brick and partly to its deformation in the press, will be produced. Such a brick cannot, by its nature, be so strong as a brick of a more homogeneous structure. Hence, unless the dies of the repress are kept in first-class order it is better not to use a repress at all. For the same reason the production of cylindrical clots to be later pressed into bricks, is undesirable.

Die-Boxes in presses require to be made in such a manner that corrections for wear and tear can readily be made. Many ingenious devices for this purpose have been invented, amongst the best being (*a*) renewable lining pieces (*b*) built up sides.

In dies or moulds with renewable liners the portions of metal which come into direct contact with the clay are in the form of thin strips of steel, which can readily be replaced when worn, without much expense being involved.

With built-up dies the four sides of the die are made loose

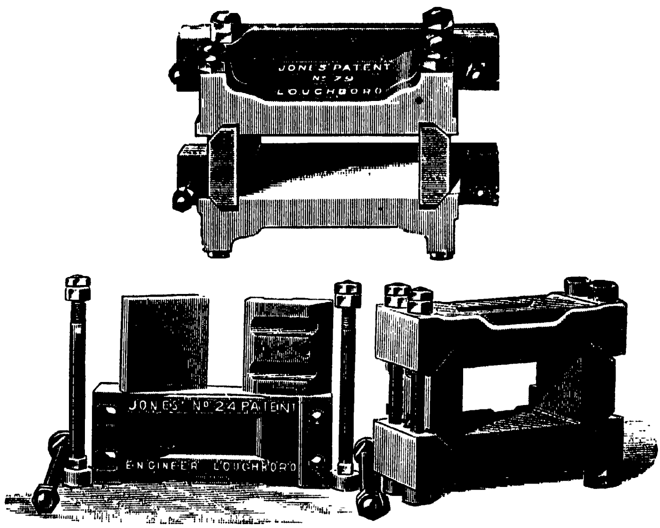

FIG. 101.—Jones' patent brick dies.

and are held together by bolts, as in the patent dies made by John Jones & Sons, Ltd. (fig. 101).

The "economic" moulds made by Sutcliffe, Speakman & Co., Ltd. are based on the principle of a mould made in two or four parts held together by two massive bolts passing through the body. Loose liners are arranged with notched edges and key-pieces to fit perfectly to each other. On tightening the two bolts, the whole mould, including the liners, is held rigidly together, but on loosening the bolts it may be readily taken to pieces and the liners turned or replaced. These moulds can be fitted to any type of hand or power press and are very cheap in actual use; they deserve to be widely known. The saving of time they effect

in relining is very great, and they are appreciated by all who have used them, on account of this convenience.

The illustrations show an "economic" mould taken to pieces (fig. 102) and put together ready for use (fig. 103). It is essential

FIG. 102.—"Economic" mould (taken to pieces).

that the dies should be kept accurate in size, as otherwise the bricks will be faulty.

Any variations in preparing the paste, or in its composition, will cause the size of the clot, or first-formed brick, to vary. To

allow for this variation the clot or brick is made small enough to drop easily into the die-box of the repress. Hence the brick does not fill the press-box neatly, and when the pressure is applied the clay is forced out until it meets the sides and ends of the box, producing a different "set" and a rearrangement of structure, which may seriously affect the final strength of the brick.

This difficulty may be partly overcome by the use of a device (such as that patented by Pullan & Mann) in which variations in

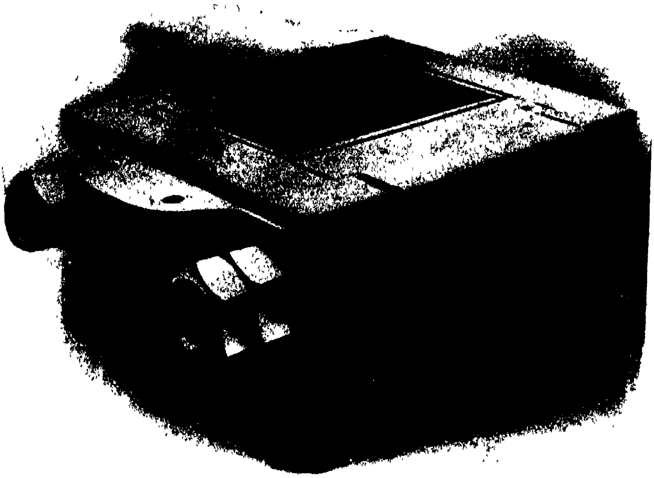

FIG. 103.—"Economic" mould ready for use.

the thickness of the original brick are automatically taken up by varying the size of the frog in the repressed article.

Surface cracks in repressed bricks which have been fired are sometimes existent before repressing, but instead of being healed, oil enters the surface indentations and cracks and prevents the surfaces from adhering. The removal of the brick from the press partially smooths over these flaws, so that it is impossible to detect them until they have been through the kiln.

The chief use of the repress is to put sharp corners and square edges on an otherwise irregular block of clay, but by exercising greater care and skill in forming the original brick, much of the repressing now practised may be avoided.

DRYING.

Plastic-made bricks usually require to be perfectly dried before being sent to the kilns as, if the moisture they contain is removed too rapidly, good bricks cannot be produced.

Hacks (p. 56) are not usually employed except for drying hand-made bricks, though in some instances they are quite satisfactory for the machine-made article.

Artificial dryers are of various types, ranging from the simple shed to the most complex of chamber- or tunnel-dryers using waste kiln-gases, live or exhaust steam, or both, and fitted with mechanical ventilators.

The main principles applied in the drying of bricks are convection, conduction, and radiation, the heat necessary being applied by placing the goods on heated floors or in a current of air warmed to the desired temperature. When no artificial heat is used, a large amount of air at the ordinary temperature will be required, and if the clay is tender it will be necessary to dry very slowly, as such clay is very sensitive to strong currents of air.

The simplest form of dryer is a shed in which is a number of racks or shelves on which the bricks are placed to dry (fig. 25). The walls of this shed are made in sections of Venetian shutters which are opened to admit fresh air, or of boards which can be taken down and an open shed produced. The roof should have shutters which can be opened to create a better circulation of air when the bricks require it.

The racks, or shelves, should be arranged with aisles or gangways between them if the shed is very large, and should not be higher than a man can reach easily whilst standing on the ground; the use of trestles wastes much time and is far from satisfactory. Ample space must be left between the top of the racks and the roof of the shed, as if this space is too small there will not be sufficient air in the shed to retain the moisture given off by the bricks unless a very strong air-current is used. Such air-currents are disastrous with many clays.

The cost of such a shed fitted with racks is by no means low (it amounts to about £800 for an annual output of 1,000,000 bricks) and the cost of placing the bricks on and taking them off the racks is also considerable. It is, therefore, advisable in many cases to substitute some other form of dryer where the annual

output exceeds 1,000,000 bricks. For small yards the use of such a shed will effect a total saving of about 6d. per 1000 as compared with hack-drying.

It is wise to erect such a shed the full width and to increase its length when a larger capacity is required, as this arrangement does not interfere so much with the working as when a series of sheds is used. The output of such a shed may be increased by laying three steam-pipes on the floor beneath each rack, or by constructing the racks of 1 in. iron pipes through which steam is passed. The use of steam is valuable when the bricks have to be made very soft, and the output of the works is too small to warrant the installation of a tunnel-dryer.

Small vertical boilers quite suitable for this work can now be obtained very cheaply, and the fuel being burnt under better conditions than when "fires" are used for drying, much heat is saved. The trouble of a limited water-supply need not be considered serious, because most of the steam can be condensed and collected at the outlet of the dryer.

The main underlying principle of the best systems of drying by artificial heat consists in the use of a small volume of air at a higher temperature in place of a large volume of cooler air. The advantages of this are so great as to make artificially warmed dryers far cheaper for large outputs than is often supposed by brickmakers who are unaccustomed to the use of heat, and the volume of air being smaller the tendency of the goods to crack is greatly reduced.

The best methods of applying heat are by no means easy to ascertain; the common idea—that of raising the temperature of the drying-shed by supplying heat to the floor—being found, on careful investigation, to require serious modification if the best results are to be obtained. In the first place, bricks placed in a heated, closed shed will not be dried completely unless their temperature is so high that it would be difficult to deal with them when dry without loss of heat (and therefore of fuel) by allowing the shed to cool. In addition to this loss of heat, the irregular distribution of heat which occurs in such a dryer is liable to give unsatisfactory results, and better drying can, therefore, be obtained more economically by the more careful use of the principles underlying the supply of heat and the evaporation of water in bricks.

When a wet brick is heated, several reactions occur of which the following are the most important:—

(*a*) The dry or solid portion of the material absorbs heat and its temperature increases.

(*b*) The moisture in the brick also absorbs heat, and if the air surrounding it is capable of absorbing moisture some of the water passes out of the brick into the air, this process of drying being continued until either no moisture remains in the brick, or until the air can absorb no more because it is saturated. In this last case the temperature of the air must be still further increased, or the air must be replaced by an unsaturated portion.

(*c*) As the moisture evaporates from the surface of the brick it is replaced by other water-particles from the interior, and the brick shrinks in size until a stage is reached where no further contraction is possible, after which simple transference to the surface and evaporation of the moisture alone take place. The amount of air used, and the temperature attained by it and by the finished bricks, will depend upon a number of circumstances. Thus, as A. E. Brown has shown, "to raise a dry brick weighing 7 lb. from 60° to 61° F. takes only 1·4 units of heat; but to raise, in the same way, the temperature of a wet brick weighing $7\frac{1}{2}$ lb., and to evaporate at the same time the $\frac{1}{2}$ lb. of water it contains, will take 537 units of heat, or nearly 400 times as much. The latter figure represents the heat yielded by the consumption of about $\frac{3}{4}$ oz. of ordinary coal. Not only so, but the heat has absolutely disappeared, and can only be recovered by condensing the vapour of the water-bath into the water again. For this reason the statements which are sometimes made that certain drying systems use heat over and over again, and that the heat is not allowed to escape, must not for one moment be credited, although at first sight they seem to be borne out by the system referred to." It will thus be seen that the supply of an ample amount of air, at a suitable temperature, is the primary factor in the drying of bricks, and the methods by which this is attained must now be considered.

Three general methods are in use:—

1. The bricks are dried by convection, by placing them on a hot floor which transmits its heat direct to the bricks, and these, in turn, warm the surrounding air and enable it to absorb the moisture evaporated, providing that sufficient air is present. In this case, the bricks are laid on the floor, or are stacked to a height of about 3 ft. The disadvantage of this method of heating is that it is wasteful of heat, the air being warmed by the bricks, and unless satisfactory means are supplied for its pro-

gressive renewal or removal, the drying is both irregular and slow compared with the amount of heat used. Such floors are not suitable for very tender clays. The floor may be heated by steam flues, by flues from coke or coal fires, or by waste kiln gases, or the dryer may be placed above or around a continuous kiln—a custom very popular in Germany but seldom used by British brickmakers.

In spite of the advantages which some other dryers undoubtedly possess, there are cases in which the drying room on top of a continuous kiln is equally satisfactory and often cheaper to work. This is especially the case where space is limited, and there is but little accommodation for a dryer on the ground level. The saving in fuel is also quite noticeable when the bricks are dried from the waste heat from the top of the kilns, even when the goods are ordinarily dried without heat except in damp weather. The cost of raising bricks to the top of a continuous kiln is often greatly exaggerated, as a simple elevator with balance weights will usually provide the elevating power, and the number of men needed is no more (and sometimes even less) than with the other forms of dryer. In short, the firm which installs a simple drying room on top of their continuous kiln need have no anxiety when they have once arranged it to suit their clay, for an error can only be made when, without attempting to understand the conditions under which the clay must be dried, a dryer is designed as a direct copy of one used by another manufacturer.

Opinions differ greatly as to the relative value of steam and fuel for heating dryer-floors; the use of gases from kilns is only employed to a very small extent, and many firms would profit by more attention to this method of working.

The gases should be drawn from the kilns under the dryer floor by means of an induction fan, placed at the farther end of the dryer, as, by this means, the gases are cooled so that they cannot injure the fan. The floor is so constructed as to distribute the heat evenly throughout, a design similar to that used for steam but with flues 18 in. deep being satisfactory. Larger flues may be used if a light floor is strong enough. The fan should show a gauge reading of ½ in. to 1 in. of water.

When steam is used, it is customary to employ exhaust steam during the day and live steam at night, if necessary. The construction of the floor is practically the same as when fuel or kiln gases are used, except that the joints may require to be rather

tighter to prevent condensation on the bricks, and the sub-floor must be carefully concreted to prevent the ground being unduly softened by the condensed steam. Some attention should also be paid to the draining away of the water produced in the flues of a steam-heated floor, and on this account the sub-floor should slope in the same direction as the steam travels, though E. Thomas has found a depth of 2 in. of water on the sub-floor to be an advantage in securing a more even distribution of the heat. The steam being of a uniform temperature, the lines of brickwork forming the flues may be broken by setting these bricks about 1 in. apart; incidentally this secures a better distribution of the steam. The floor should be divided into a number of separate sections, each about 10 ft. wide and each capable of being worked independently. This serves to economize steam and facilitates the regulation of the drying.

The steam from the boiler enters a transverse flue at one end of each of these sections from a pipe controlled by a special cock or valve, finally escaping through a similar transverse flue at the other end of the section. It is important that a vent for the escape of steam, as well as a drain outlet for the water, should be provided at the end of each section. Some makers prefer to let the steam enter a transverse flue in the centre of the dryer instead of at one end; this is desirable if the dryer is more than 30 ft. in length, but otherwise it is more convenient to have the steam-inlet pipes near to a wall and so out of the way.

The use of drain pipes to form the flues of a drying floor should be avoided, they are seldom, if ever, satisfactory, and if the spaces between them are filled with solid ground the heating power of different portions of the floor is very irregular.

A steam floor built in sections, 30 ft. long and 10 ft. to 15 ft. wide, will dry ten bricks per week for every square foot of surface if properly built and cared for. If the flues are covered with iron plates instead of with cement a slightly larger output may be obtained, but the use of iron presupposes that the bricks can withstand somewhat rapid heating.

An excellent arrangement of flues for a steam-heated floor consists in laying bricks end to end on their edge with their sides 6 in. apart (centre to centre) on a sub-floor made of concrete 2 in. in thickness, and covering these bricks with others laid flat as "stretchers". A finishing cover of cement, 2 in. thick, or iron plates, 3 ft. square, completes the floor. The cement covering

is preferable, as it does not transmit the heat so rapidly as do iron plates.

The lowest bricks are set with their ends 1 in. apart until a width of 10 to 15 ft. is obtained, when they are set close and jointed with mortar or cement so as to form a series of independent sections. In place of bricks, hollow blocks may be used where the weight to be carried by the floor is not excessive. The thickness of material between the steam and the bricks to be dried is less than with a brickwork floor and the heat is transmitted more readily. Such a floor is, however, more easily damaged by carelessness in the use of the barrows employed for carrying off the bricks.

Floors heated by coke, coal, or kiln-gases have the flues arranged similarly to those employing steam (p. 157), the fires being arranged at one end of the dryer and a chimney at the other. The sections should not be more than 8 ft. wide for each fire used, and the thickness of floor above the flues should be greater nearer the fires than at the other end, so as to secure as even a temperature as possible in the bricks. The whole of the flues should slope slightly upwards towards the chimney-end and the gases should be collected in a transverse flue before being taken to the chimney. A floor heated in this way will dry 10 to 12 bricks per square foot per week if very carefully watched and with a favourable clay, but with tender clays serious difficulties may be experienced.

When kiln-gases are used they are delivered into a transverse flue at one end of the floor through a flue connected directly to the kiln. In order to prevent a back draught on the latter it is usually necessary to employ a fan at the other end of the dryer in order to draw the gases through the floor. A blowing fan cannot well be used, as the gases are too hot, except when obtained from continuous kilns. It is, however, a mistake to attempt to use the gases from properly constructed continuous kilns for this purpose, as their heat should have been used in the kiln itself with the exception of a small amount necessary to carry the gases up the chimney.

The use of waste gases from single intermittent kilns for drying has not received the attention it deserves, yet when a number of such kilns are connected to the same shaft it is not usually difficult to connect them to the dryer and so use the heat the gases contain. These gases must not, however, be allowed to come into contact with the bricks or the latter will

be discoloured, though so long as gas-tight flues or pipes are used for containing the gases no harm of this sort can occur. The hot gases should be taken from the *top* of the kilns.

The hot floor is one of the oldest forms of artificial dryer known, and for ordinary building bricks it has now been largely replaced by tunnel dryers, though for fire-bricks, terra-cotta, and in many somewhat small brickyards a hot floor is still used.

After the bricks have been partially dried on a hot floor they are usually stacked, in order that they may take up less room before they are taken to the kiln. This is a waste of labour which should be avoided when possible, but is sometimes unavoidable. The bricks may be stacked in a variety of ways, and suggestions in this connexion may be gained from a study of the illustrations in Chapter VIII on setting and burning.

Some clays permit the bricks to be stacked very openly, whilst with others the bricks must be placed very close together so that

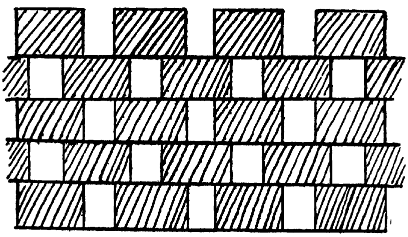

FIG. 104.—Bricks set in open chequer work.

they may dry very slowly. In the latter case, a simple chequer-work arrangement of the bricks should be used (fig. 104), but if an open setting is required the arrangement shown on this page (fig. 105) is to be preferred, an "air flue" (*a*) running through each set of bricks.

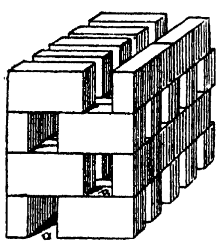

FIG. 105.—Bricks drying on hot floor.

If the bricks are set in blades or walls, these should be about 8 in. apart so as to permit of easy handling and ample air-space for drying. The height of such blades or walls will depend upon the stiffness of the bricks, but ought not to exceed 4 ft.

2. The goods are placed in special chambers—usually of a tunnel form—and the air is drawn through these chambers, being heated directly and communicating its heat to the bricks.

In tunnel-dryers the air is heated, and the goods are dried chiefly by their contact with warm air, though they are, to a limited extent, heated by radiation from the pipes, etc., in the dryer. The basic idea in a tunnel dryer is the same as that in a continuous kiln, with the difference that, instead of the goods remaining stationary and the heat travelling (as in a kiln), the goods usually, but not always, travel in the dryer.

In most cases the bricks are placed on cars and are moved through the chambers, which are made sufficiently long to hold a number of cars at a time, but dryers using warm air in which the goods are stationary are also employed. These latter have the disadvantage of wasting some heat and the goods must be taken to the dryers, set, and again loaded on to cars or barrows before being taken to the kiln, thus necessitating a loading, setting, and reloading which are avoided when cars are used. On the other hand, the cost of the cars is avoided.

The best results are obtained (providing the goods can withstand the slight shocks produced when a car is removed from a dryer, the remaining ones moved forward, and a new one inserted) when the bricks remain on the cars during the whole drying period, but with delicate articles, and where the cost of cars would form a serious charge on the capital of the firm, it may be necessary to place the goods in a tunnel until it is filled and to remove them when dry, though a little consideration will show that this method is more costly both in handling and in heat than when the goods move forward through the dryer.

Tunnels in which no cars are used must be filled, the goods dried, and the tunnels then emptied. Such tunnels are therefore intermittent in action. When cars are used the dryers are generally made for continuous working. The chief use of carless dryers is for specially tender clays which will not stand the shocks of the cars; but if these vehicles are properly constructed continuous dryers will be found preferable.

A simple form of continuous tunnel-dryer is shown in fig. 106 in section and in fig. 107 in plan. In this the cars (C) carrying the bricks to be dried, enter at the cool end (B) and are moved intermittently (i.e. each time a car is drawn out of the dryer) towards the end (A). Hot air enters the dryer through the flue (A) and is made to travel in the opposite direction to

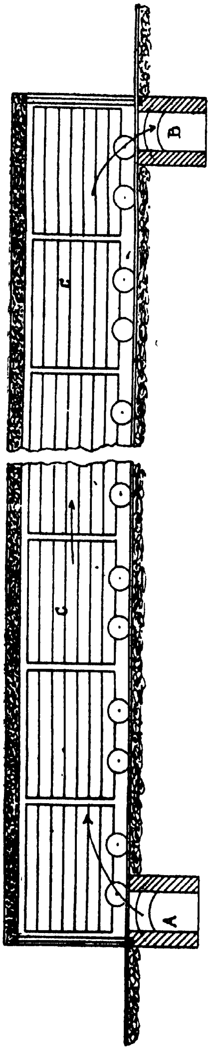

Fig. 106.—Section of tunnel-dryer.

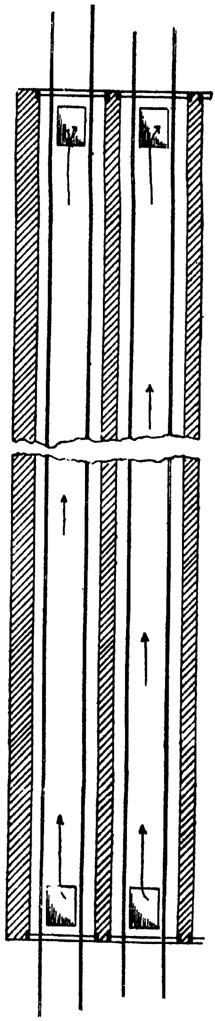

Fig. 107.—Plan of tunnel-dryer.

the goods, the movement of air being indicated by the arrows. When charged with moisture and cooled, the air passes out through the flue (B). Only one track or tunnel is shown, but any convenient number may be placed side by side. A convenient size of tunnel is 120 ft. long, holding sixteen cars, each carrying 360 bricks. When properly constructed and worked, a tunnel-dryer should dry even tender clays in twenty-four hours, or an average of four bricks per minute.

It has been shown, by A. E. Brown, that a tunnel-dryer is most efficient when the air enters it at 170° F., and leaves it at 82° F., but this latter temperature is too low in practice, because the air is so charged with moisture as to make it difficult to avoid its condensation on the goods just entering the dryer. In some instances bricks are found to weigh several ounces more after a short time in the dryer than they did before entering it; this is due to condensation of moisture on them. The result is that, with a dryer of this type (i.e. one in which the air and goods travel in opposite directions to each other), the air is discharged at about 90° to 95° F., and a slight loss of heat thereby is accepted as inevitable.

The movement of air is effected by means of a fan or a special chimney stack. It is heated by passing over a special heater using fuel or kiln-gases, or by mixing it with gases derived from the combination of fuel, either directly or as the waste gases from kilns. The latter method is not satisfactory when the colour of the finished bricks is important on account of the impurities in the gases.

To prevent the bricks at the top from drying too rapidly, some means of controlling the air currents and regulating their velocity in different parts of the dryer must be provided. Otherwise the topmost bricks will be dried more rapidly than the lower ones. This is often overlooked by amateur dryer-builders.

The Blackman Ventilating Co draw air partly over grates (G) (fig. 108) on which the fuel is burning, and partly through other openings protected by gauze doors, so arranged that the air is mixed with passing through the fire-brick flues (R) before it passes the fan (V) and enters the dryer through the upcast (A) as already described. Such an arrangement is known as a "slab-heater". It is very effective, as the flues (R) tend to heat the air very uniformly when the heater is properly cared for, but the warming of the air by its admixture with the products of combustion of the fuel is a serious drawback except for common

goods. On this account the tubular coke-heater (fig. 109) made by the same firm, in which the air is kept pure and is heated by passing through iron pipes, is to be preferred. In it the gases produced by the burning of the coke pass around the iron pipes, heating them, and then out through the chimney.

Slab-heaters lose a serious amount of heat when above ground, hence the Sutcliffe Ventilating Co. place theirs below the ground level, and employ a different arrangement for regulating the amount of air passing through and over the grates and that used to dilute the products of combustion.

The "Aero" dryer used by H. Raynor at Witham, Essex, is similar to those by Blackman & Sutcliffe, but an induced draught

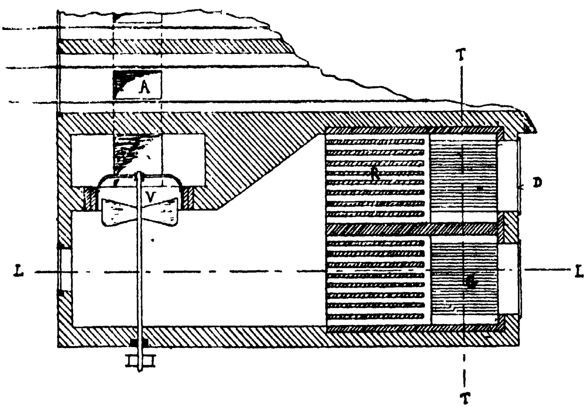

FIG. 108.—Plan of Blackman heater.

fan is placed below the ground level at the opposite end of the dryer to that at which the stove is fixed. The air, heated in a slab-heater or in any other suitable manner, enters an expansion chamber and then passes through a square hole (inlet-valve) in the floor of each tunnel. After traversing the tunnel it passes out through another square hole (outlet-valve) in the floor to the fan and the outside air. A chimney fitted above the exit (fan) end of each tunnel enables the dryer to work at night without the necessity for running the fan if the outlet-valve is closed. Control of the heat is obtained by means of dampers. Thus, heat is prevented from entering a tunnel by covering the inlet-valve with a damper. The draught is also controlled in the same way at the outlet-valve. An important feature in the

construction of this dryer is that each of the outside walls consists of two separate walls of 4½ in. width, with a 1½ in. space between them. The draught from the fan draws any warmth from this cavity that may penetrate the inner 4½ in. wall back into the tunnels, where it is again utilized for drying.

Steam-heaters are placed under the warm end of the tunnel if of the tubular form, but when steam pipes are used they are generally placed in the floor of the tunnel just below the rails on which run the cars carrying the bricks. Tubular steam heaters usually consist of a cylinder 10 to 20 ft. long fitted with about 200 tubes, each 3 in. diameter, through which air is blown by a fan, and around which live or exhaust steam circulates at a pressure not exceeding 60 lb. Such a heater shown diagrammatically in figs. 109 and 110 is supplied by several firms,

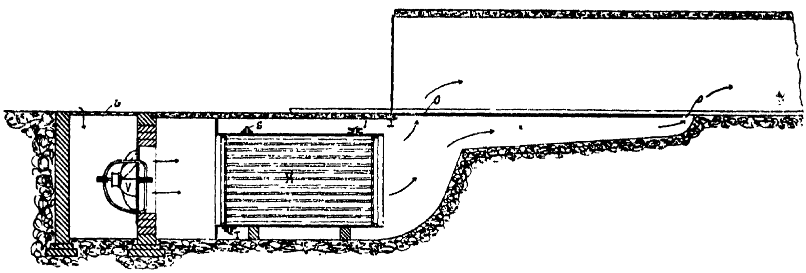

FIG. 109.—Heater and fan in position.

notably the Blackman and Sutcliffe companies just mentioned. An excellent steam heater of American design is shown in fig. 111.

The Wolff dryer has steam pipes placed under the floor of the tunnels to about three-quarters of its length, as shown in fig. 112. The pipes are arranged in four or more sections, the steam passing from one to the other in turn, and leaving any condensed water in the 5 in. connecting or "service" pipes. The amount of steam is so regulated that none escapes from the last section. All the water produced by condensation is taken to the boilers. The roof of this dryer is double and has several openings at the cool end which may be used to increase the upward movement of the air and to take it direct to the shaft. The volume of air supplied in this dryer is comparatively small, rarely exceeding 2500 cub. ft. per minute in each tunnel.

Drying is slower than in some other types of tunnel-dryers,

being seldom completed in less than fifty hours and occasionally requiring five days.

Condensation on the goods is often heavy, owing to the air being highly charged with moisture at the entrance end of the tunnel, and a preliminary "tempering chamber" about 40 ft. in length is, therefore, used to prevent this deposition of water on the bricks. In short, the Wolff dryer is economical in regard to the amount of steam it requires, but it is capable of much improvement in several ways.

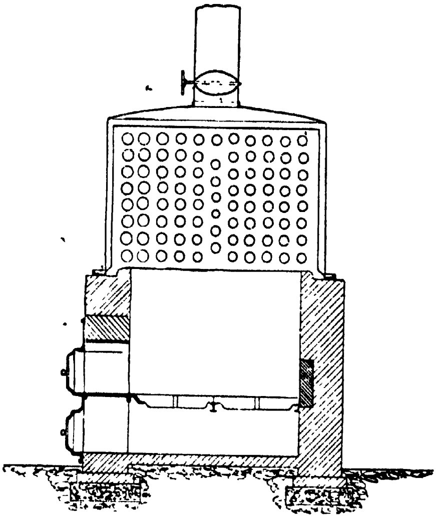

FIG. 110.—Tubular heater for coke.

When kiln-gases are used in a tunnel-dryer, they should be passed through somewhat wide metal pipes on account of their corrosive powers, unless the smaller piping can be cheaply and easily replaced. The flues or pipes should be some distance below the goods so as to allow some circulation of the air heated by them, or the bricks will be irregularly dried.

It is, usually, best to employ waste steam as far as possible, and only to finish the drying with air heated by passing around flues containing kiln-gases.

The most efficient and effective drying of bricks is obtained by the use of the tunnel-dryers in which both goods and air move in the same direction. The air is cold as it enters the dryer, and

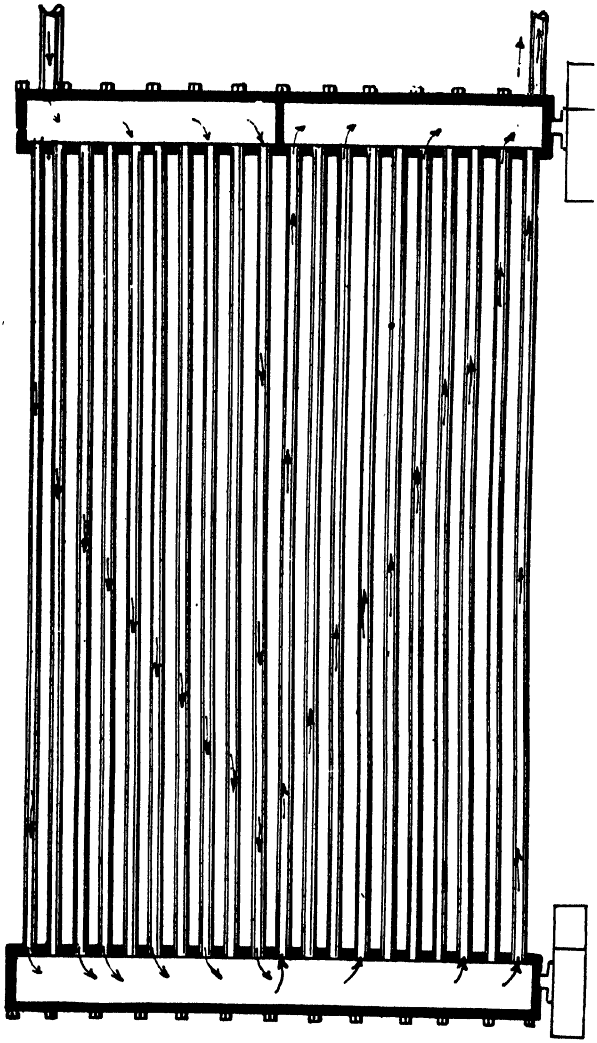

Fig. 111.—American air heater.

it and the bricks are both warmed progressively, as they travel forward, so that the air passes out of the dryer warm and leaves the bricks hot and dry.

As the heat-carrying power of the air increases very rapidly with an increase in its temperature by working in this "direct" manner, there is no danger of condensation on the goods, and the drying can be accelerated as soon as sufficient moisture has been removed from the goods to enable this to be done.

As exhaust steam does not supply heat at a sufficiently high temperature, the hot end of the dryer must be supplied with gases from a furnace or kiln.

A typical dryer of this kind is one patented (fig. 113) by A. E. Brown. A series of furnaces or slab-heaters (H) is placed below the hot end of the dryer; and the air from these passes through a series of pipes (C) which are separated by broad transverse chambers (G) covered with sheet iron (*d*) to facilitate sweeping or obviate the defects of expansion. At the cool end of the dryer these gases pass through a series of tubes (K), around which the air for the dryer circulates, and are taken to the chimney by a fan (not shown). Any additional heat that may be required is supplied by steam pipes (*e*), and kiln gases carried in pipes or flues may replace those from the slab-heaters (H) in whole or in part.

The air for drying the bricks enters below the floor level at (*f*), passes around the heater (K) and into the tunnel at (*h*). It then traverses the entire length of the tunnels in the same direction as the cars, becoming warmed by and taking up more and more moisture from the bricks. It flows in a gentle stream, and by reason of the overhead radiation does not require diverting by baffles or keeping in spiral movement by side fans. There is consequently an entire absence of surface drying, and its attendant warping and cracking of the goods. Below the roof (D) a ceiling flue (F) is formed either by tubes or, as here shown, by a sheet-iron ceiling (*b*). Into this flue the hot air now enters at (*k*), travelling in the reverse direction, to the collecting flue (M) by which it reaches the fan. The heat from the hot air radiates downwards through the ceiling.

The air necessary for combustion of the fuel of the furnace enters the cooling chamber at (*l*) and passes off the hot cooling bricks from the openings (*m*), picking up the heat given up by the dried bricks in cooling. The necessary suction of the air and furnace circuits is created by a fan placed at the cool end. Some amount of condensation of the moisture dried out of the bricks

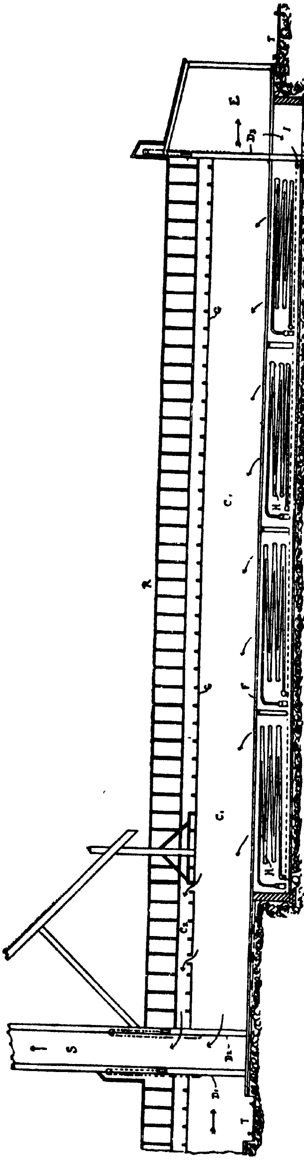

FIG. 112.—Wolff dryer.

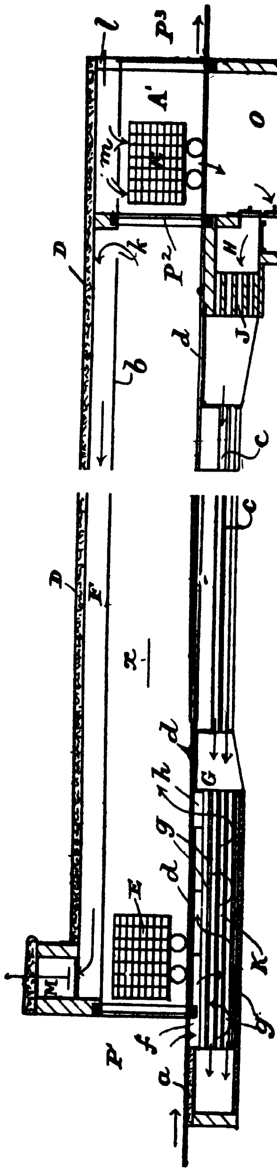

FIG. 113.—Brown's tunnel dryer.

occurs in the ceiling flue (F). The fan thus produces simultaneously the circuits of the furnace gases and the drying air.

When treated in a tunnel worked in this manner, most (even tender) clays may be dried within thirty hours, as the amount of air used is very small in volume. It is, during the greater part of the drying, so charged with moisture as to be nearly saturated. Excessive surface-drying and strong air-currents are thereby avoided, and many clays which will inevitably crack when dried in other ways can be readily and satisfactorily dried in a tunnel of this description under careful management (see p. 175).

The Wolff dryer, when worked in the opposite manner to that usually employed, is converted into a dryer of this type, and so gives far better results for the reasons just mentioned.

The Moller and Pfeiffer dryer also works on this plan, and is in extensive use on the Continent. This dryer has, however, a number of fans at the side, so as to give a spiral or corkscrew

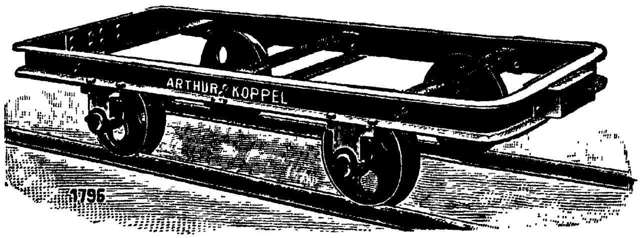

FIG. 114.—Single deck brick-car.

motion to the air in the dryer, this air being repeatedly passed over the heaters and goods in its spiral journey. The makers claim that they can dry any clay, no matter how tender, in twenty-four hours, and many clays in a shorter time, and so far as the author can learn they appear to have fulfilled this promise in most instances. There is, in fact, no doubt that this type of dryer is the most efficient on the market, but the cost of fans makes it expensive to install, and, for most purposes, a similar effect can be obtained without these fans by providing a false ceiling, arranged as in fig. 113, to give an overhead radiation.

The power required to drive a fan suitable for a dryer need not exceed 2 b.p.h. for four tunnels yielding together 15,000 bricks per day. The fuel and steam consumption is distinctly less than in any other form of dryer, amounting to about 1¼ cwt. of fuel per 10,000 bricks dried at an average of four per minute.

The cars used for carrying the bricks may be of the single (fig. 114) or double deck (fig. 115) type. The method of loading them

depends upon the softness of the bricks, pallets being used or not, according to the height to which the bricks can be stacked on each other.

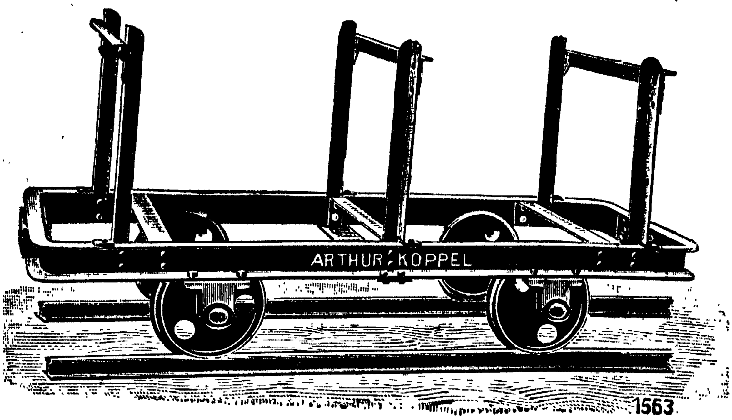

FIG. 115.—Double deck brick-car.

On single deck cars the bricks may be set eight high, or seven high if pallets (fig. 116) are used, but double deck cars are preferred as being more stable. For very soft bricks, cars with racks to hold plain pallet boards (fig. 117) are preferable.

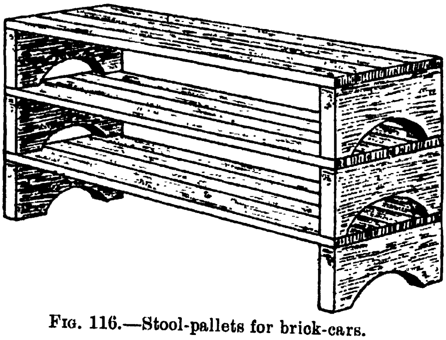

FIG. 116.—Stool-pallets for brick-cars.

All cars should have roller-bearings (fig. 118) and steel wheels of 12 in. diameter. A suitable rail-gauge is 20 or 24 in., the wheel base being 30 or 42 in. respectively. The narrower sizes are preferable for ordinary work.

As the dryer rails are usually at right angles to the presses it is generally necessary to employ a transfer-car (fig. 119), which

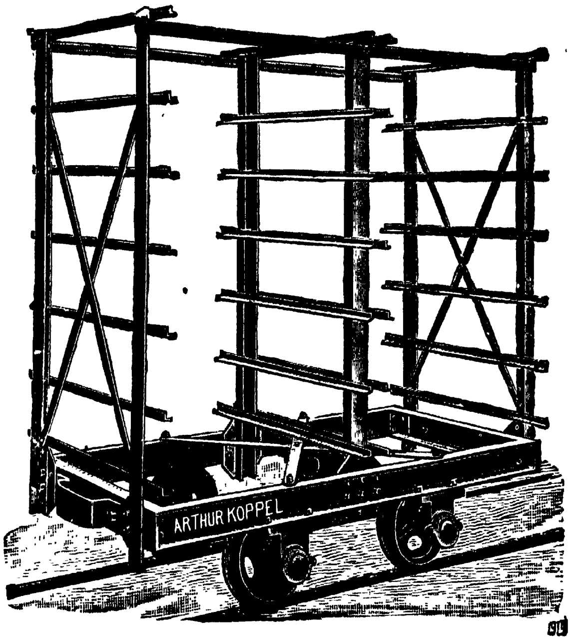

FIG. 117.—Cars for soft bricks.

runs on a track placed in a trench transversely to the ends of the dryer. The brick-car is run on to this transfer-car and the whole

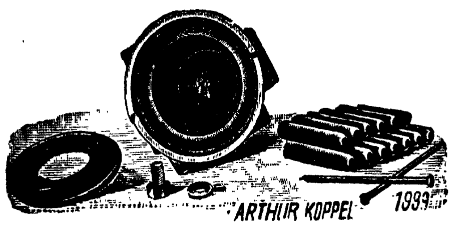

FIG. 118.—Roller bearings for brick-cars.

is wheeled until it is in the right position for the brick-car to enter the tunnel. A similar car and track receive the dry bricks

from the other end of the dryer. An ordinary brick-car costs £4 to £6, a transfer-car about £9.

The rails in the dryer should weigh at least 14 lb. per yard and should be securely bolted with fish plates. They should be laid so as to slope 1 in 80 towards the exit end, though some brickmakers prefer a level track.

The cars are usually propelled through the dryers by means of a winch working on the car about to enter the dryer. A small pulley on a horizontal axis is mounted below the rails about 6 ft. inside the dryer, and over this is passed a steel rope with a hook at one end, the other being wound round a hand winch. The hook is attached to the back of the car, and on working the winch the car is drawn forward into the dryer and the door closed. When it is necessary to put another car in the dryer the hook is

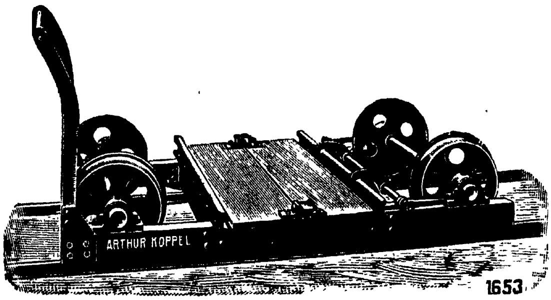

FIG. 119.—Transfer-car.

taken off and placed at the back of the new car, which is then in its turn made to enter the dryer by operating the winch.

Other appliances of a more or less automatic character may be used, and in some yards the slope of the rails is sufficient to enable a strong man to do all that is needed, without any winch or other mechanism being necessary.

In general construction the outer walls of dryers are built of 9 in. brickwork, the inner ones being thinner. The roof may be of galvanized iron or concrete; a wood, felt, or iron roof, well pugged with sawdust or sand is preferable, as it does not conduct—and so waste—heat so readily. A sliding door, properly counterbalanced so as to rise easily, should be provided at each end of each tunnel. By constructing a dead air-space in the roof and outside walls, much loss of radiated heat may be prevented and fuel saved.

At the outlet-end (particularly if there is a sloping track) it is wise to have some safety arrangement, so that in the event of a car breaking loose it will not damage the door. For this reason some dryers have the exit door hung with hinges at the top, a chain hung over a pulley, and attached to the counterpoise, being fastened near the bottom, but the simple rising door fixed without guides is equally satisfactory if not made too heavy.

The cost of erecting tunnel-dryers varies greatly, but a fair average for each thousand bricks' capacity is about £45 for the "direct type" and £35 for the "inverse type". The apparently greater cost of the former is, however, saved in actual working and upkeep costs and in the fewer worthless bricks produced. Broadly speaking, a tunnel-dryer costs the same as a continuous kiln for the same annual output.

All continuous tunnel-dryers must work day and night, the cars being withdrawn at regular intervals both day and night. The kiln fireman can usually attend to this at night, as it usually only means inserting three cars and withdrawing three others.

The objection to running a fan at night urged by some brickmakers has no real foundation, as wherever steam is employed in a dryer it necessitates a night stoker, and he can attend to fan and dryer at the same time as the boiler.

To get the best results from any dryer, means must be provided for testing the amount of moisture and the temperature of the air in it as well as the volume of air used. For this purpose wet-bulb thermometers should be employed, a recording thermometer being also very desirable. Directions for using these can be obtained with the instruments.

In comparing the relative cost of working with different dryers *all* matters must be taken into consideration, as certain firms' representatives are sometimes inclined to minimize the importance of such subjects as "back-pressure" and "an odd load or two of coal" each night. Yet these trifles may make all the difference in obtaining an accurate comparison. In calculating the cost of drying bricks by various methods, it is fairest to take the number of good and perfect bricks as the basis, for the others are practically useless. Most dryer builders do not like this method of calculation, for it tells against poor or unsuitable dryers, but it is the correct way, nevertheless. Another factor which is often omitted in comparing different kinds of dryers is the depreciation and interest on capital; in other words,

the special machinery, etc., needed, and their effect on the cost of the dried bricks.

It is specially necessary to see which form of all those suitable for a particular clay is cheapest in actual use; depreciation and interest charges must be included in this, as well as the material used in construction (wood, brick, or iron, or all three). The cost of working and of the labour required also need consideration.

The choice of a dryer is not so simple as most people suppose, if the really best dryer for the particular clay is to be selected, and in most cases *impartial* expert advice should be sought.

No matter how skilfully a dryer may be constructed, unless it is properly managed it may prove a failure, particularly with a tender clay. It is, therefore, necessary that the men in charge pay full attention to instructions given to them.

In drying *tender clays*, the chief requirement is to use air fully saturated with moisture to raise the temperature of the bricks to that at which drying may most suitably take place. So long as the air used for this is sufficiently moist no drying or cracking can occur. When the bricks are at the right temperature, the moisture-content of the air used may be reduced in gradually increasing amounts until the bricks are strong enough to allow dry air to be used. In this manner, the tenderest clays may be satisfactorily dried in a comparatively short time. One method of keeping the air around the bricks sufficiently moist is to heat them in a closed chamber, air only being admitted very cautiously when the bricks are at 100° C. Instead of using a closed chamber it is often sufficient to cover them with wet canvas and to cover this with tarpaulin until they are fully heated. The tarpaulin may then be gradually removed, and afterwards the canvas also. This principle is simple of adoption in almost any brickyard, even where the output is not sufficient to warrant the installation of a special tunnel-dryer.

In these ways the moisture is sweated out with a minimum of air and consequently the liability to damage is at a minimum, shrinkage is made regular, and warping and cracking are avoided.

Bleininger has found that clays which are difficult to dry because of their high shrinkage, may be rendered normal by heating the raw clay as it comes from the pit in a rotary furnace at a temperature of 250° to 400° C. This destroys part of the plasticity-forming power of the clay, and enables the material to be dried in the same manner as less plastic clays. The cost is

very slight. The addition of sand, burned clay, or other non-plastic material will also convert many tender clays into those of normal strength. It does this by separating the particles from one another and so increasing the pore spaces. Mixing clays with boiling water instead of cold, during the pugging or tempering, has a similar effect, and in addition causes the bricks to harden slightly as they cool before entering the dryer.

Transport.—Plastic bricks are carried on barrows or cars, or occasionally on belt or other conveyers. When continuous tunnel-dryers are used, cars are invariably employed.

Kilns.—The kilns used in burning plastic bricks are of the single, intermittent, and continuous types. These are described in Chapter VIII, as the kiln used bears little or no relation to the method of manufacture employed.

General.—For the successful manufacture of wire-cut bricks the clay should be thoroughly and carefully prepared; all material which is too coarse to pass a No. 10 screen being rejected. A constant and uniform composition of clay and water must be maintained so as to obtain a constant shrinkage, and for this, thorough and careful tempering and mixing is necessary. Sufficient water should be worked into the clay, but an excess must be avoided. The machinery must all be maintained in good order, and the drying, setting, and burning must be carried out under constant skilled supervision, if the best results are to be obtained.

CHAPTER V.

THE STIFF-PLASTIC PROCESS OF BRICKMAKING.

WHILST almost any clay of sufficient purity can be made into bricks by means of one of the processes described in the previous chapter, these methods are far from being the most economical so far as certain clays are concerned. The proportion of water which it is necessary to mix with the clay in order to produce a plastic clay may easily amount to more than 1 lb. of water per brick, and this involves the use of a large amount of time, or of artificial heat, in its removal.

There has, therefore, within recent years, arisen a practice amongst brickmakers whereby the clay is worked up into a much stiffer and less plastic paste with a smaller quantity of water, or in some cases with no water at all, so that the large amount of water necessarily added in making bricks by the plastic process is partially or completely avoided, and the bricks require but little drying, and frequently can be set directly into the kiln. These processes in which little or no water is used are known respectively as the "stiff-plastic," "the semi-plastic" or "semi-dry," and the "dry-dust" processes; the first of these will be described in this chapter.

The advantage of the stiff-plastic process lies in the fact that when properly carried out the bricks need but little drying; they are stiff and easy to handle, and may be repressed, if desired, immediately after they are formed. At the same time they resemble in structure and characteristics those made by the plastic process far more than when the drier processes are used. In connexion with repressing it must be remembered that some firms of brick-machine makers do not consider the "stiff-plastic" brick at all, but employ a press as an integral part of the machine, and consequently understand by a repressed brick one which has been passed through two distinct presses.

The disadvantages of the stiff-plastic system [illegible] cannot be used for certain classes of clays of an[illegible]

sticky character—though even with these much may be done by the judicious admixture of sand or other non-plastic materials—and there is a great temptation when it is used for brickmakers to hurry the clay direct from the machines to the kiln and to heat up too rapidly, with the result that the finished bricks are badly discoloured and are often warped. Had they been dried properly before being sent to the kiln, in many cases first-class bricks would have been produced.

The advantages of the stiff-plastic system are, however, so obvious and so important, that there is little doubt that this will be the chief process of brickmaking in the near future. The disadvantages are much more apparent than real, and with reasonable care can be overcome with the majority of clays suitable for brickmaking.

The process of making bricks by this system requires the provision of a comparatively dry clay, or one in which a wet clay can be mixed with a large amount of dry material so as to make a relatively dry mixture. This is necessary, because in this process the clay is ground and sifted in a relatively dry state, and this sifting and grinding cannot be effected by the same plant if the clay is very moist or damp. It is specially uitable for certain shales, which are becoming increasingly opular for the manufacture of hard burned, slightly vitrified uilding bricks.

Briefly, in the stiff-plastic process, the clay or shale is brought from the pit in wagons and fed into a grinding mill, generally e edge-runner type, with revolving perforated pan, though a minary breakage of the large lumps is desirable. The clay und dry or in a slightly moist state, and is then taken by an or to the screens, of which there is generally one to each The clay which passes through the screens goes down a nto a mixer, where a little water is added and the whole is oroughly mixed. It next goes into the making-machines ressed into rough blocks or "clots" about the size of a These are then repressed, this latter operation giving k its proper shape, making the "well" or "frog" and on the name of the firm. The bricks are then dried, ry, and taken to the kilns. Drying is avoided when his being the great advantage claimed by the stiff-ess, though even where it cannot be entirely avoided greatly reduced. As the bricks when taken to the resumably, in the same state as those made by the

plastic process, similar kilns may be used. These are described in Chapter VIII, but it may be noted here that for large outputs some form of continuous kiln should be used for bricks made by the stiff-plastic process.

The material must be sufficiently ground, and for the best bricks must be able to pass through a sieve with twenty holes per linear inch without leaving any residue, though for common bricks a coarser sieve may be used, one with eight holes being popular. It must be mixed into a paste of even composition and of constant stiffness, and the machinery used must be kept in first-class order. If these matters are attended to and the material is suitable, no serious difficulties should occur in the manufacture of stiff-plastic bricks.

The material used in the stiff-plastic process may be of almost any kind that will make bricks, providing that it is not too sticky. Shales and some loams are best for the purpose, but some boulder-clays can be successfully used. As all these materials are somewhat variable in composition when first won, it is necessary to mix them thoroughly, and for this purpose it is better to use a grinding mill than crushing rolls, as the former has a powerful mixing action. The material being practically dry, the advantage of grinding mills with perforated revolving pans is available, and this type of mill should be used except under extraordinary circumstances.

A large mill is desirable so that there may be no trouble in obtaining a sufficiency of ground material. With a small [illegible] the working of the plant is troublesome, but with a larger [illegible] any excess of clay over that required can usually be stored [illegible] the it is needed. Moreover, the cost of running a large mill [illegible]cient, per ton of material ground, and, consequently, if the p[illegible] the well arranged a notable saving in power is effected. T[illegible] the full advantage of this saving, the mill and the rest of t[illegible] it is must be capable of working independently of each other[illegible] not

The output of all edge-runner mills for dry materia[illegible]other closely connected with the sizes of the pieces and the[illegible] in which they are fed. If too little material is supp[illegible] (fig. obvious that they cannot work at their full capacity. [illegible] about seldom realized by those in charge of such mills that [illegible] dry or the output is also reduced, even though the overfee[illegible] correct temporary. To secure the best results an edge-runne[illegible] by at- be supplied with small pieces and in as regular a[illegible] weight possible, and the ordinary method of emptying a [illegible] raising [illegible]ntil the [illegible] of the

material into the mill by means of a "tippler" or similar contrivance is not calculated to give the best results.

The best means for feeding the mills must be decided upon by those in charge, as it is largely a matter of cost. Thus the ideal way (regardless of expense) is to attach a preliminary stone-crusher and a mechanical feeding appliance to the mill, so that the supply of material to the latter is independent of the amount brought from the clay pit. Such appliances require power and cost a certain sum for installation, and it is sometimes (though very seldom) found to be cheaper to run the mill below its capacity, instead of using them to supply it with a regular and suitable feed.

The method, sometimes used, of keeping a man at the mill to break up large pieces and shovel in the material at frequent intervals, is invariably more costly than the employment of a breaker and feeding appliance, and is not so satisfactory. To some extent feeding appliances may be avoided by the use of very small wagons, so that only small quantities enter the mill at a time. The wear and tear on these small wagons and the cost of haulage must, however, be taken into consideration when the question of a feeding apparatus is under discussion, and they do not prevent lumps from entering the mill.

One great difficulty accompanying the introduction of automatic breaking and feeding appliances into existing works, where they would undoubtedly save money, is the lack of room in the t-house for such an apparatus to be inserted. In several ances where the mills have not been capable of supplying ient material under existing conditions, and where it was sary to work them at their maximum capacity, the author ccessfully employed the following arrangement:—

material is brought from the pit in wagons of the usual nd the contents of these are tipped on to a sloping tray with sheet iron and provided with sides about 18 ins. This tray is perforated with holes about 3 in. diameter, or be constructed of bars placed this distance apart. The tween the clay and the ground is enclosed to prevent e of dust and to keep the material dry, a similar grate, placed at the bottom of the slope, and receives the which has failed to pass through the perforations or e bars. These large pieces of material are either by hand, with a hammer, or are passed to a stone-ore they are sent to the mill, this breaker being so

placed that it delivers the material below the tray just described. All the pieces less than 3 in. diameter are taken to the mill by some form of feeder, or where no such appliance is used they may travel by gravity down a chute.

The saving thus effected in wear and tear of machinery and in power, and the increased output obtained, has more than repaid the cost of installing this preliminary riddle in those cases where it has been used. Its only disadvantage is the space it requires,

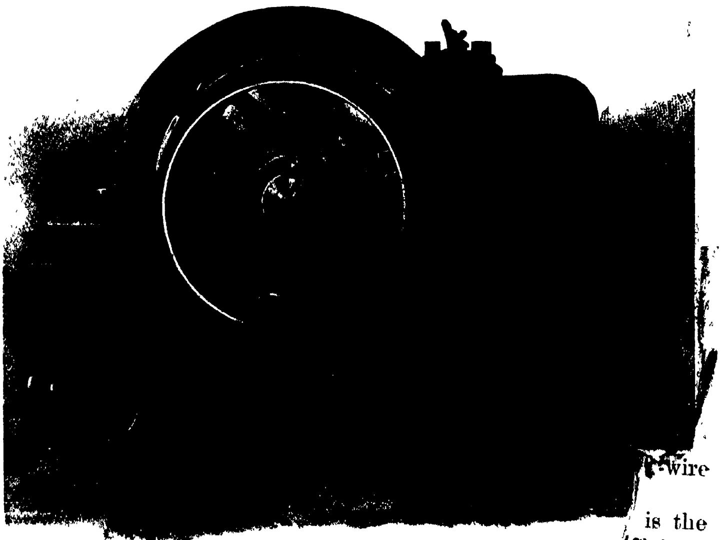

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Fig. 120.—Blake-Marsden stone-breaker.

as the lesser attention needed at the mill enables the ame it is
to attend to the riddle and breaker. do not
Stone-breakers are made in a variety of forms, but other
most suitable for crushing clay lumps is that shown in
and made by several firms in this country. It requires late (fig.
little power and attention, and soon saves its cost wh of about
hard material has to be ground. for dry or
As the product need not be crushed very small e correct
no need for the jaws to be set closely, and conseq nd by at-
can be arranged to give a large output if the mak a weight
sulted before such a machine is purchased. The ja and raising
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examined occasionally and any wear and tear made good, as the machine will waste power if it is out of order.

A pair of old crushing rolls set 2 in. apart also makes a good breaker for materials of medium hardness.

Mill Feeding Machines.—Various arrangements are in successful use for feeding mills with a dry material, the most advantageous being (*a*) belt or trough conveyers fitted at the base of a slope or hopper, and provided with some scoop or other appliance which shall prevent their being overloaded (fig. 121). (*b*) Spiral

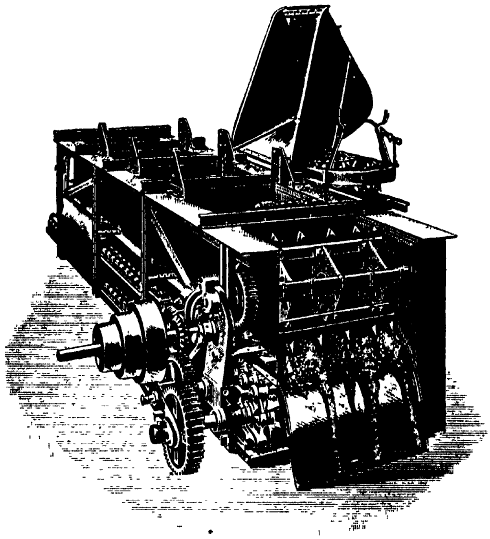

Fig. 121.—Haendle mill-feeder.

ers or worms which rotate and carry the clay forward in quantities and at a definite speed. A number of worms arranged side by side to deliver direct into the mill or conveyer belt; this latter arrangement being used when hin the mill-house is too limited to admit the insertion ding worms. (*c*) A pan (similar to that of the grinding ided with one or more scrapers, and rotated, or with ase (fig. 122), so that the material is withdrawn at a e which is independent of the manner in which the pplied.

these appliances has its advantages and disadvant-

ages, and a lengthy experience with each is necessary before a satisfactory choice can be made. The author has had but little opportunity of working with the last named (*c*), and of the machines in classes (*a*) and (*b*) has usually found worm-conveyers to be more accurate and reliable, though somewhat slower and requiring rather more power. They have the further advantage that large lumps are not carried forward, though if these are of very hard material they may stop the machine or break it. If, however, a preliminary crusher is used no danger from this source need be anticipated. Granted, however, that a

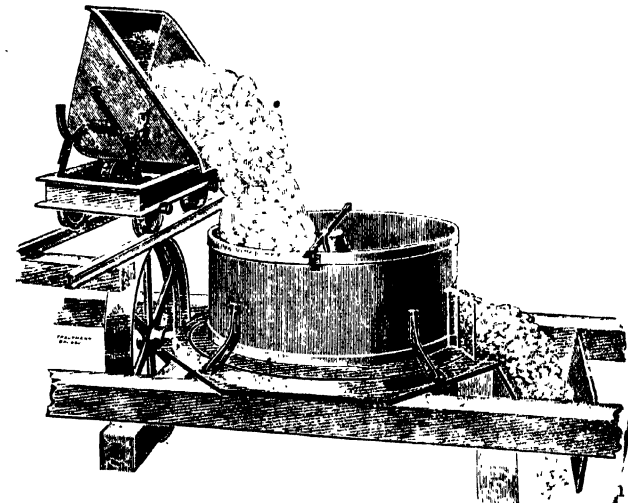

FIG. 122.—Rotary mill-feeder.

brickmaker realizes the advantages to be derived from su-
ing his mills with a constant regular supply of material,
not long be at a loss as to the appliance which is most s
for his requirements.

Grinding Mills.—All grinding mills for use in th
plastic process of brickmaking should be provided with a
pulley, or friction clutch, arranged so that the machine
stopped instantly if necessary. They should also be m
run independently of the rest of the plant, so that if th
shortage of clay they may be run at night, or if too m
is being ground they may be stopped and the pow t
Each evening the mill should be run almost empty,

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and raising
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be cleaned out to prevent iron bolts, etc., remaining in the pan.

Usually mills of the over-driven type (fig. 123) are to be preferred, the machinery being more accessible and less liable to be clogged with dust, though the under-driven type (fig. 124) should be used in cases where unusually light runners may be employed; this is seldom the case. Mills of the edge-runner

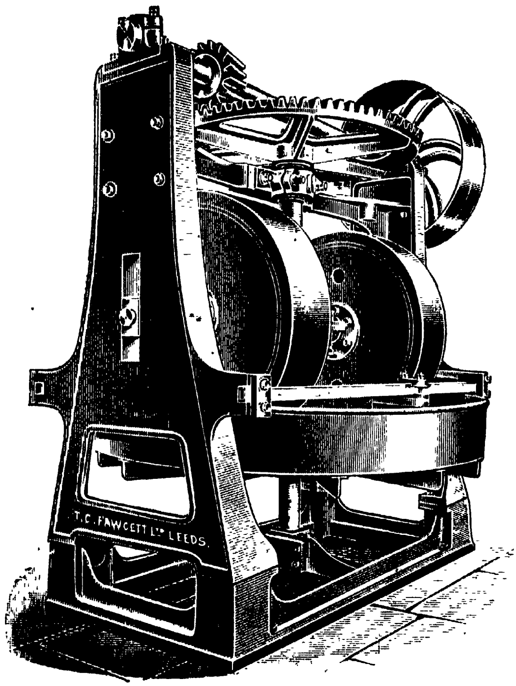

FIG. 123.—Over-driven grinding mill.

ith revolving perforated pans, are most suitable for this f brickmaking, though those with a fixed bed are much The perforations should not be too large or the screens overworked and power lost in regrinding, nor should they nall or the output will be too low.

ally speaking, the perforations (figs. 125 and 133) should s than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. diameter, the latter rarge for most clays, $\frac{1}{8}$ in. or $\frac{1}{4}$ in. diameter being the

best size. Slots are somewhat less satisfactory than circular perforations, as the product is coarser and more irregular.

The arrangement of the perforations on the pan is a matter which has received very careful study, particularly on the Continent, where it is generally considered that the runners should

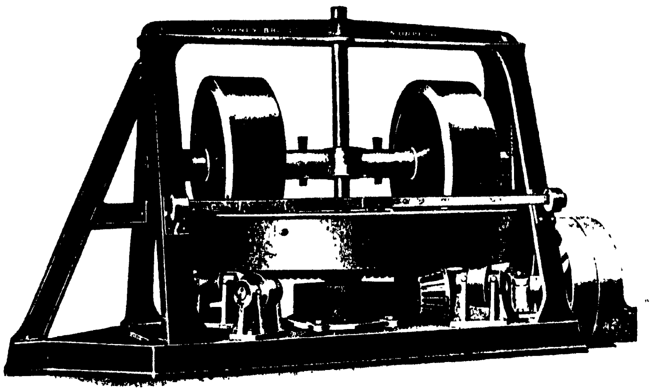

FIG. 124.—Under-driven grinding mill.

not pass over the perforations, but that these should be at either side of the runner path. An excellent arrangement is for the material to pass under one of the runners, then over a perforated portion of the pan, under the second runner and over another perforated portion, any uncrushed material being then pass
under the first runner again for further reduction.

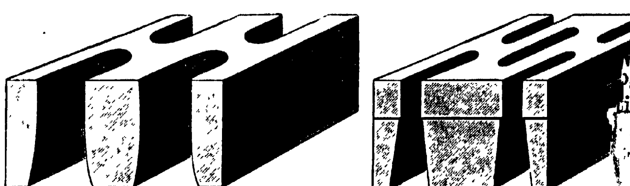

FIG. 125.—Slotted perforations in grinding pan.

Where the perforated portions of the pan are m
manganese steel they may occupy the runner path, and
though coarser output obtained. For fine grinding the
must be on a solid part of the pan whilst it is being
The pan generally used is 9 ft. or 11 ft. diameter, sm

being undesirable. It should revolve at least thirty times per minute, but must not travel so fast as to throw up much dust, though this may be retained by judicious damping. The pan is rotated by means of a pinion and crown wheel operating on a vertical shaft which carries the pan, the rollers being independently carried on the side frames of the mill. The lower end of the vertical shaft terminates in a footstep bearing, the construction of which and its maintanance in good order are very important.

It should be of bronze metal and work as nearly frictionless as possible. This is best effected by running it submerged in an oil-reservoir, so that it does not heat or wear under the most exacting conditions. The oil-reservoir should be fed through a pipe connexion located at the outer edge of the pan. A large base plate underneath the step should be provided to facilitate adjustment in all directions. It should scarcely be necessary to point out that the whole of the mill should be strongly constructed, as it is subject to sudden and severe shocks in use. When of large diameter, several loose-running wheels (sometimes called anti-friction supports) may be placed underneath the pan so as to restrain the vibrations when unusually large pieces enter the mill. Care should, however, be taken that these loose wheels do not become clogged with dust, or they may increase the amount of power required to drive the mill.

The edge runners or rollers may be all in one piece (fig. 126) as shown, or they may be provided with renewable wearing hoops or rims, caulked on with cement or wedged on with ...oden slips (fig. 123). This latter method is preferable as it ...bles a renewal of the rims to be readily effected.

...When the pan is empty, the runners should not rest on the ...ing plate, but should be suspended by powerful springs in ...a manner that when the material is fed into the pan the ...eight of the runners comes on to it, because the springs are ...ted from following the runners. Should some hard metal ...tally get into the pan the spring buffers will prevent the ...s from seriously damaging the pan in bumping over it.

...e runners must be kept flat on the "tread" or they will ...ind properly. They should be very heavy (from 2 to 5 tons ...the general tendency being to use those which are rather ...nd the whole machine should not (for the 9 ft. size) weigh ...3 tons. It will then need 25 to 30 b.h.p. to drive it under ...onditions.

...runner should be mounted on a separate shaft, the two

being bolted together at the centre in such a manner that they are able to rise and fall, preferably independently of each other.

Most mills would be improved by greatly lengthening the hubs of the runners. If these are too short the runners soon lose their uprightness.

The scrapers used to direct the material under the runners require occasional adjustment. They must have their lower edges parallel to the pan but not quite touching it.

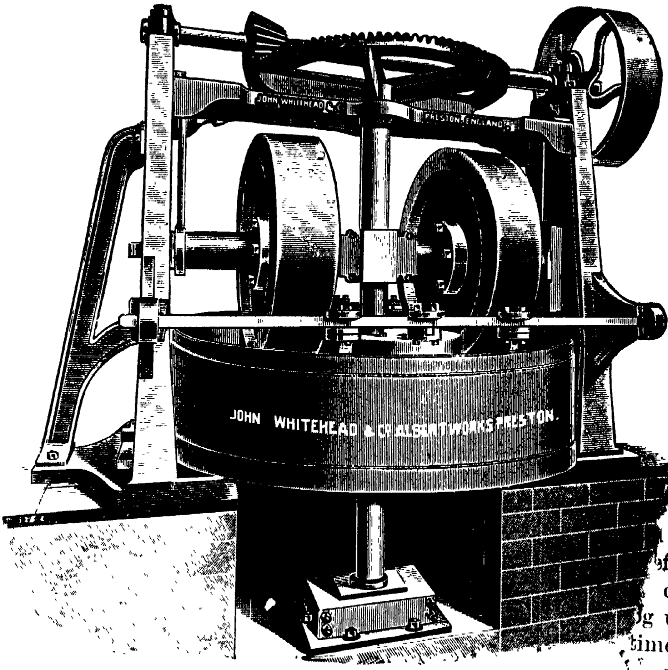

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FIG. 126.—Mill with solid edge runners.

The material which has passed through the perforatio the pan may be received on a base plate or in what is terme "open base," the latter being preferable when there is suffic space available.

late (fig.
e of about
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he correct
and by at-
g a weight
and raising
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tom of the

In the ordinary pattern of mills (with a base plate) the u side of the revolving can is provided with one or more sc (fig. 123) which collect the clay as it falls on the base plat shown) and push it over or through an opening in the latt

then falls into a "well" from which it is raised by a bucket elevator. These scrapers, of course, wear away in time, and so require regular attention to keep them in proper adjustment.

In the "open base" pattern of mill (fig. 127) scrapers are not

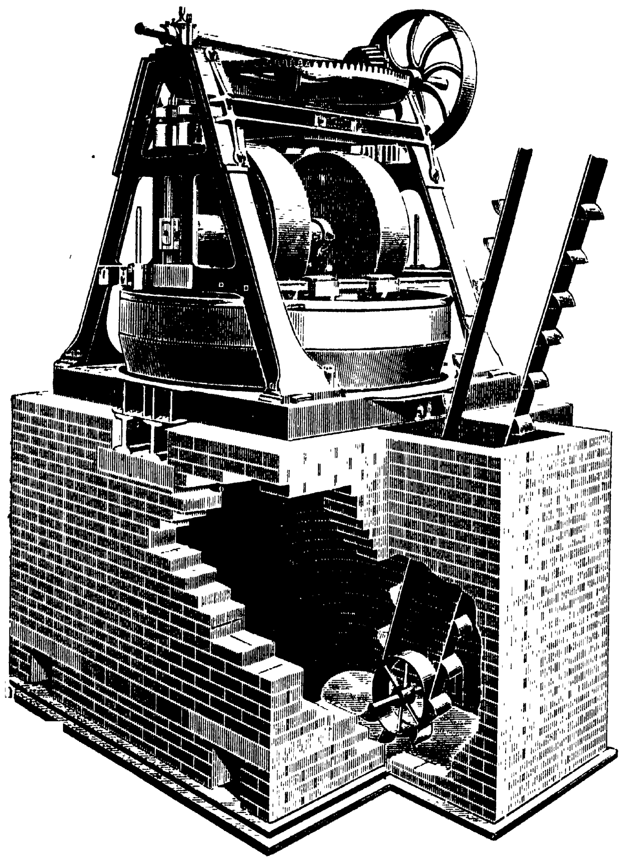

FIG. 127.—Open base grinding mill.

essary, and so the friction of the mill is reduced nearly 50 per
n This means a very important saving in the power necessary
iving it. In such a mill the material which has passed
gh the perforations falls on the inclined face of the founda-
f the pit and so passes easily to the elevator.

Mills of both types are supplied by the principal makers of brick machinery, but James Buchanan & Sons, Liverpool, also supply a pan with conical runners (fig. 128), which they claim

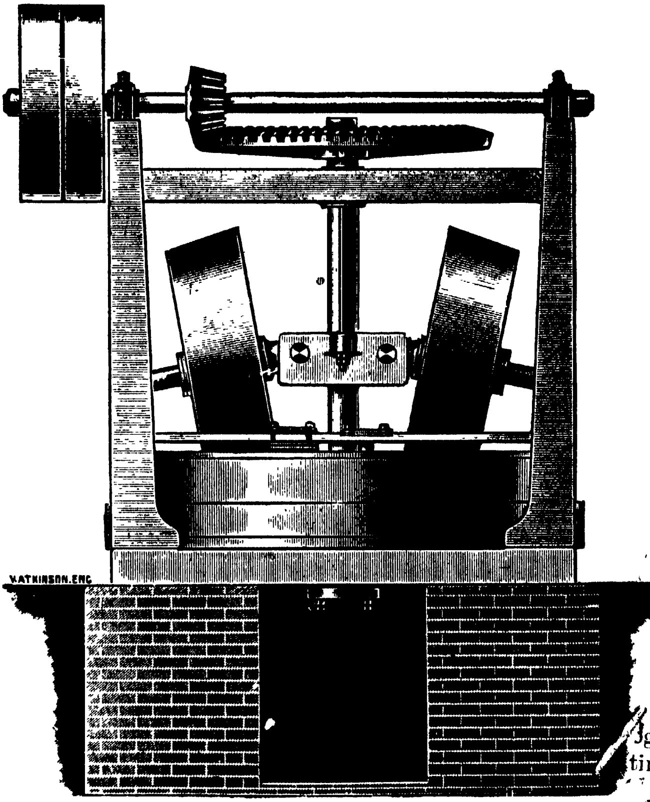

FIG. 128.—Grinding mill with conical runners.

gives a greater efficiency and larger output than the cylind[rical] runners.

In America, it is not unusual to see two pans geared to[gether] and working side by side, one receiving the "residue" or [tail]ings" from the screen and the other the clay from the w[ell], but both delivering into the same well. This arrangem[ent]

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very useful when hard material is present in the clay, and is now used in this country by several fire-clay and shale grinders.

Several Swiss and German firms favour the use of grinding mills fitted one above the other (Buhler's patent, fig. 129), but in this country their use is restricted to a few firms with unusual facilities for delivering the clay at a high level. Usually the pans in Britain work quite independently of each other, a sufficient number being used to secure the desired output. This arrangement is advantageous when the output of the works varies greatly, but for a large and steady output it is more economical in

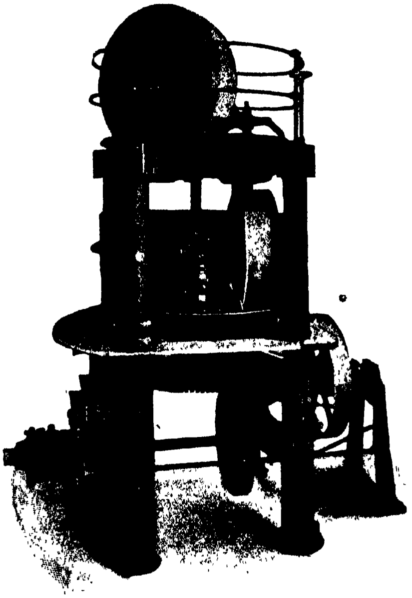


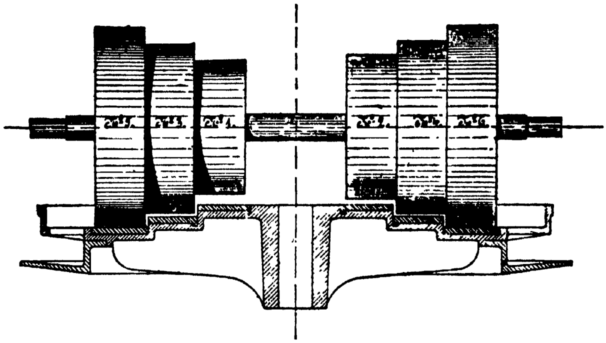
FIG. 129.—Buhler's two-stage mill.

lower to let a rough mill do the first crushing and, after the material from this has been screened, to pass the coarse residue a second or even to a third mill.

The use of three rolls in one piece, with a pan arranged in ei as shown in fig. 130, is sometimes found valuable. Machines this type have been much used on the Continent, and were in-duced into this country in 1907 by John Whitehead & Co., Ltd. far they have not become popular, though their advantages undoubted where a material needs a large amount of crush- nd mixing. In the machine shown, the material is fed in the centre, is crushed by the smallest pair of rolls, passes to the next step and is treated by the second pair of rolls, after falling to the lowest step it is treated by the third pair , and finally discharged from the machine. Such an ap- is more compact than those of the type shown in fig. 129,

but is intended for similar materials. For most brick-clays they are not necessary.

Elevating.—For elevating the ground material from the grinding mill to the screen, an elevator may be used, having buckets or pockets fastened on to a belt (fig. 131), or to chains. The belt elevator is the most used, and has the advantage over the chain elevator that it can travel at nearly any angle, and the contents cannot fall out; but the chain elevator can only go almost vertical, because there is nothing between the two chains



Arrangement of Runners in Patent Multiple Edge Runner Mill.

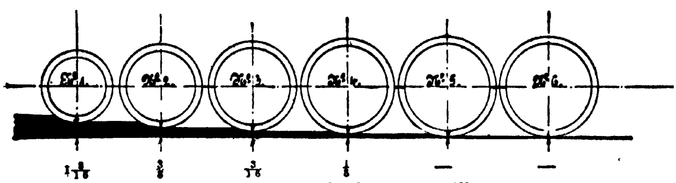
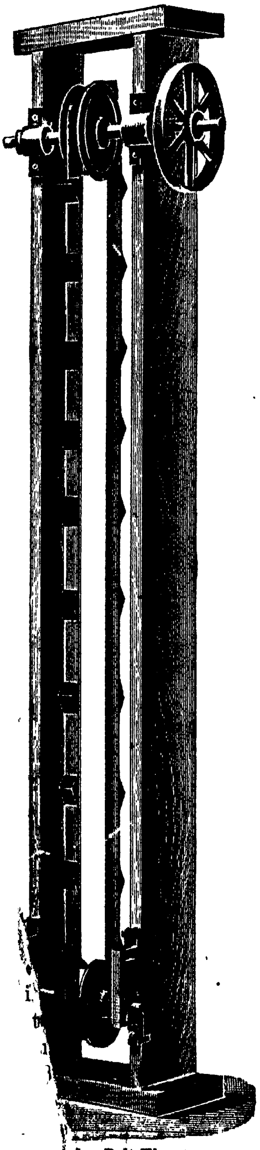


Fig. 130.—Multiple runner mill.

to stop the clay from falling out, though some chain eleva-
are made to swing from the chain so that when going hori- e
tally or at an angle the buckets keep the right way up an to
not spill their contents. The elevator must be run at a
suitable to the screen used. ion

The buckets on elevators are generally iron oblong box td.,
are fastened to the belts by two or three rivets (fig. 132).
buckets should be shallow, so as to spread the clay on the ze of
Deep ones are less efficient for this purpose. pro-

Numerous small buckets are preferable to fewer la ich is
as they give a more regular feed.



—Belt Elevator.

Screens, Sieves, or Riddles are used for separating the coarse and finer particles of material from each other, the former being returned to the mill for further treatment.

Two chief forms of screens are in use at present: (*a*) the stationary sloping screen; (*b*) the revolving screen.

Stationary screens consist, usually, of a sloping tray 4 ft. to 6 ft. in length, and 18 in. or more in width, the tray itself being made of wire gauze, perforated sheet metal, or of a number of wires

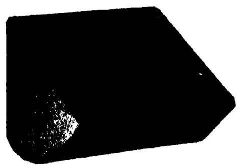


Fig. 132.—Bucket for raising crushed clay.

arranged side by side (piano-wire screen).

The wire-gauze screen is the oldest, but is seldom very efficient, as many particles lodge on the cross wires and soon clog up the sieve. At the same time it is used by many firms who do not know the advantages of other forms of screen.

The perforated steel plate (fig. 133), if arranged at an angle of about 45 degrees, is admirable for dry or almost dry materials. The correct angle can readily be found by attaching a rope carrying a weight to the top of the screen and raising or lowering the screen until the distance from the bottom of the

screen (*a*) (fig. 134) is equal to the height of it (*b*). The perforations in it may be much larger than the size of the particles to be separated, so that the wear and tear is very slight, and in most cases no "rapping" or vibration is necessary.

The author has repeatedly found that with dry clay a screen with perforations $\frac{1}{8}$ in. diameter will act precisely the same as a revolving screen having 20 holes per linear inch. The mathematical reason for this curious behaviour need not be given here; it is interesting, however, and suggests why some brickmakers have failed to appreciate this type of riddle—they have used too fine a screen.

The screen should be fixed at the lower end but hung at the upper one with chains so that its angle may be adjusted to suit the clay. The sides of the screen should be about 9 in. in height,

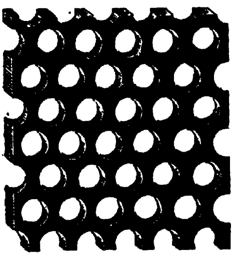


FIG. 133.—Perforated steel plate.

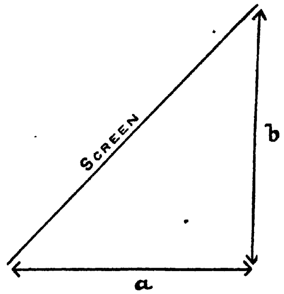


FIG. 134.

and a canvas or sheet-metal cover should be used to prevent loss of dust. The upper part of the screen should have a plain metal plate (called the "feed plate"), attached so that the material may spread itself over this before travelling down the screen. If necessary one or more "guides," or baffle plates, may be placed above this plate to secure the proper distribution of the material. If much dust is produced the screen should be enclosed in a light wooden casing, or should deliver the clay into a special chamber.

When more difficult material is being treated a modification of this screen—"The Newaygo"—supplied by T. C. Fawcett, Ltd., may be employed (fig. 135).

This consists of a large sheet of perforated metal, the size of the perforations depending on the fineness of the required product. This sheet or screen is mounted on a frame which is

hung by chains at a suitable angle, and in such a way that the screen may be kept vibrating by the blows of a series of hammers acting on "anvils" on the framework and screen supports. The clay is fed into a trough which runs along the top of the frame and in which runs a spiral conveyor, so arranged that the clay is discharged over a "weir" in a perfectly regular stream over the whole width of the screen.

It will thus be seen that in this arrangement the advantages of the perforated sheet are fully recognized, and where baffle plates cannot be arranged satisfactorily the use of a special trough, spiral and "weir," will be found advantageous in the securing of a regular and even feed of clay. Indeed, such an appliance is usually superior to any arrangement of baffles, and the amount of power needed to drive it is too small to be worth consideration.

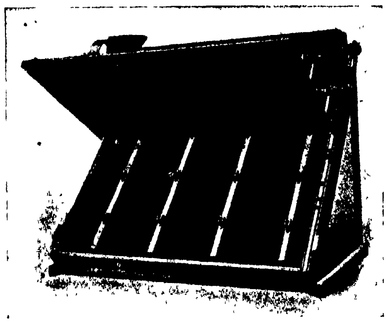


FIG. 135.—Fawcett's "Newaygo" screen.

As in other stationary screens, the fine material falls through the sieve into a hopper or on to a receiving floor, and the coarse material runs down the screen into a chute and is returned to the mill.

Piano-wire screens are made by arranging a number of wires parallel to each other, and fastening them with a stretching key in a manner identical with that used in pianos. This screen was invented by Adam Adams, and the ones of his design, supplied by Whittaker & Co., Ltd., consist of a strong frame over which the wires are stretched and tensioned at one end with screw pegs. The pitch of the wires, which determines the mesh, can be varied by the insertion of fresh pitching-bars which are detachable from the frame, and the adjustment of

the wires is thus readily made. As ordinarily used, the wires supplied for these screens are too thin, and consequently hard pieces of shale are apt to cause them to open. By using thicker wires this objection may to some extent be avoided, though these screens are never really suitable for clays containing hard, *thin* pieces of shale or rock-clay. For other clays, when not overloaded, they are good.

The standard meshes for piano-wire screens vary from 8 to 20 wires per linear inch.

As with all other riddles, the piano-wire screen should be set so that the elevators deliver the clay to a spreading-board at the top of the screen and not directly on to the wires. By using the spreading-board the clay is delivered on to the screen constantly, and is spread evenly over the entire surface so that it screens more rapidly.

Revolving Screens were formerly very popular, but have largely been replaced by the piano-wire or perforated steel screens. In the revolving screens the clay enters at one end, which is elevated, and causes the clay to gravitate towards the lower end. As the screen revolves, the fine material passes through the mesh of the screen, whilst the coarser material passes out through the lower end and is returned to the pan for further grinding.

The screen is usually 4 to 9 feet long with an average of about 6 ft., and about 3 ft. in diameter. It is generally mounted on a timber-frame in simple bearings, and should be provided with ample oiling devices. The frame may be covered with perforated steel plates or with wire-gauze, with any size of opening desired, the usual sizes being $\frac{1}{8}$ in. to $\frac{1}{20}$ in. If the cylinder makes twelve revolutions per minute this will usually be sufficient. Perforated metal is seldom satisfactory in a revolving screen. The frame may be cylindrical (fig. 136), or hexagonal, the latter being cheaper to repair as it enables the gauze to be nailed to six frames, each of which can be taken out when needing repair, and replaced far more rapidly than when a cylindrical sieve requires patching.

Revolving screens must, usually, be fitted with a "rapper" to shake the material through the holes. This produces a large amount of dust, and necessitates the screen being boxed in if effective results are to be obtained. Fixed screens, on the other hand, can usually be left uncovered, a mechanical rapper being seldom necessary.

When damp material has to be screened it is often useful to have a battery of steam pipes below the screen. Fig. 136 shows a

cross-section of a revolving screen, supplied by C. Whittaker & Co., Ltd., with this arrangement, and fig. 137 an adaptation of it to stationary screens. In each case the steam circulating through the iron pipes keeps the sieve warm, and reduces the amount of clogging. It is, therefore, especially useful during wet weather.

The screen, of whatever type, must always be fitted in such a position that it can readily receive clay from the elevator and return any coarse material to the mills. The chief points requiring attention are that the runs or chutes shall be as short and as steep as possible, but never at a greater angle than 45 degrees, i.e. the height should never be more than the distance along the level (see p. 193). They should be closed to prevent loss of dust,

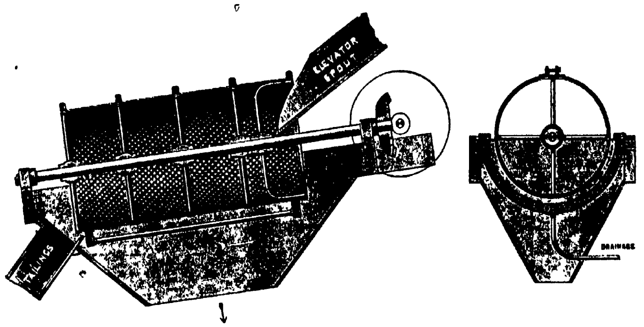


FIG. 136.—Round revolving screen.

but made so as to be readily opened in case of stoppage and also for facilitating cleaning or repairs.

STIFF-PLASTIC BRICKMAKING MACHINES.

The clay is mixed into a stiff-plastic paste by the addition of a little water and treatment in a mixer or pug-mill (p. 103) or both, and the clay is then made into a clot which is afterwards repressed into a brick.

Several types of machines are used in the stiff-plastic system of brickmaking, but nearly all of them first form a clot and then repress it. In the most satisfactory ones, the clot is exactly the shape of a brick, so that the repressing merely consolidates it but does not in any way alter its shape. A cylindrical clot has mechanical advantages in that it can be rolled from one machine to another, but it can only be used for a limited number of clays

owing to the necessity of altering its shape so much in the repressing.

Each of the machines described has special advantages for certain clays; some of these are obvious, others will be discovered from the description, and others again can only be appreciated as

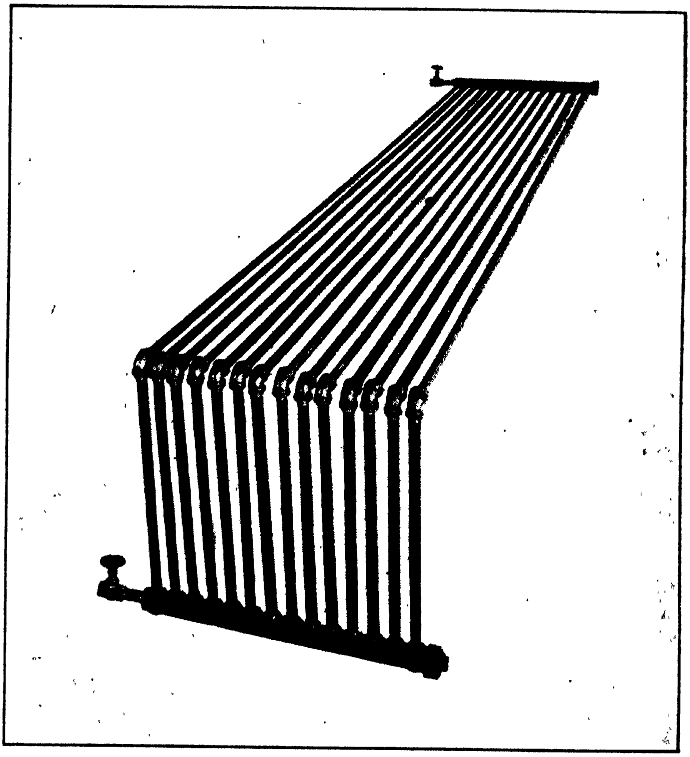


FIG. 137.—Steam-pipes for use below screen.

the result of experience. Clays vary so much in composition and character that a machine may work splendidly in one district, and yet give results inferior to another machine when working in a different place. Under such conditions, complete comparisons of the different machines are practically impossible.

Three distinct classes of clot-making machines are in use: (a)

that in which the clot is made in dies contained in a round revolving table; (*b*) that in which the die forms part of the circumference of a drum, and (*c*) that in which sliding dies are used. The pug-mill may be an integral part of the machine, or it may be separate, though the former has the advantage of enabling the mill to press the clay directly into the clot dies. The daily output of each class of machine is 10,000 to 12,000 bricks.

The chief precautions to be observed in making stiff-plastic bricks are to ensure that the dryness and fineness of the clay, the amount of pressure in the pug-mill, the consolidation and mixing of the clay paste, and in the distribution of the pressure in the final press, are all sufficient yet not excessive.

Clay is such a peculiar material that, though it can be made into articles of almost any desired shape, when once a definite shape has been given to the plastic mass this shape must not be altered if it is desirable that the article should retain its full strength. On this account the clay, as delivered from the pug-mill, must not be made into a clot materially different in shape from that of the finished brick. Those brickmaking machines in which the clot is of a different shape to the finished brick are, from this point of view, less satisfactory than others, though in the case of machines constructed by the best known makers, a slight difference in shape is found to be of little or no consequence. Hence the argument as to the necessity of retaining the shape of the finished clot must not be carried so far as to militate against the use, for example, of the Fawcett duplex machine, or Buchanan's and Johnson's machines, in which a clot with a slightly rounded top is produced, though it is quite legitimate for the makers of other machines to claim superiority in this respect.

In judging the value of brick-machines a small point like this is, however, only one out of many which have to be taken into consideration.

It is important that the clay should be delivered with sufficient rapidity from the pug-mill to the clot-mould to fill it completely and suddenly; if it is filled in stages, as is always the case when filled slowly, laminated portions or layers will be produced, and the bricks will be weaker than they should be. The necessary speed of travel can always be given, when not otherwise obtainable, by the addition of a short length of worm to the end of the pug-mill shaft. This addition may necessitate the use of an exceptionally long pug-mill or mixer. It is also important

when using a vertical pug-mill, to slacken the speed of its rotation when not delivering into the mould, as, otherwise, a large amount of power is wasted by the pressure of the clay against the plate in passing between the apertures forming the clot-mould. The liners of the clot-mould, and particularly of the final press-mould, must be kept in first-class order and require frequent renewal. Any attempt to economize in this direction is usually futile, as it results in the production of defective bricks. It is usual for the liners of the clot-mould to be simply chilled, but this is a mistake from the brickmaker's point of view. To obtain the best results they should be planed so as to get a perfectly even and true surface.

Lubrication must be carefully watched or great loss of power, as well as excessive wear and tear, will result; on the other hand too much oil or grease is a nuisance, and is more of a hindrance than a help. In some presses, arrangements are made for the insertion of automatic lubricators, and these, when properly made and adjusted, are more economical than when oil is applied by hand. The dropping of oil direct on to the brick or inside the die should be avoided; a piece of felt or some other absorbent material of a similar nature will apply the lubricant in as even a manner as possible.

When the clay sticks in the press-box, the common idea that more oil is necessary should not be accepted until it is found that the fault is not due to incorrect stiffness of the clay or to the irregular working of the machine.

Most of the failures in the working of the stiff-plastic system are due to the attempts to shorten the process of manufacture by omitting weathering, tempering, or pugging and drying. Most clays are of such a nature that unless they are treated in one or more of these stages they cannot be made into good bricks or tiles. It is difficult to say which of these stages is most important, for they are all equally necessary in certain cases, and the omission of, or part omission of, any one of them may prove vital to success.

When a clay is stored in a soft, plastic condition the distribution of the water throughout the mass will become even in course of time, but in a stiff-plastic mass this distribution is less easily effected; and when, as in most cases, no storage of the mass is attempted, there is a strong tendency for the faults due to irregularities in mixing and composition to show themselves in the finished articles. In consequence of all the widely different

characteristics of various clays, it follows that no particular brickmaking machine can be equally well used for all of them.

The selection of the best machine for a particular clay should, therefore, be made with the aid of competent and disinterested advice, based on experience with and knowledge of the clay, of various machines, and of certain special tests which must be carried out. In the purchasing of brickmaking machines, the actual cost price is a matter of much smaller importance than is generally supposed, as it will pay the brickmaker far better to spend a few more pounds in obtaining a machine which is suitable in every way to his needs rather than to purchase another machine, on the recommendation of the makers or that of a neighbouring brickmaker, without any tests being made; especially if he find later that the few pounds he saved in the first cost have been spent many times over in lower output, more frequent stoppages, or greater repairs than would have been the case had the other machine been used. The following example will illustrate this more clearly:—

In a certain part of the Midlands are three brickyards, A. B. and C., within close proximity to each other. A. has a strong and somewhat sticky, but otherwise good, clay overlying a considerable bed of sand, and finds that the machinery best adapted to his needs is that made by D. B. has a drift clay, different from the clay's used by his neighbours.

C., on the other hand, has a clay that cannot be used without much admixture, being more of a loamy character, and finds the machinery supplied by E. quite suitable. Some years ago B. bought a plant similar to that used by A., but finding it not altogether satisfactory, and having to extend his works, he installed a plant similar to C. and discarded the older one. Having had to extend his works still further, B. has now gone into the question more carefully, and with the aid of skilled advice has considered the whole question in a much more thoroughly technical manner than was previously the case. A careful study of the outputs of the machines supplied by D. and E. (similar to those used by A. and C. respectively) convinced B. that as far as his works were concerned he was not getting as much as he should do from the power expended. Attempts from the makers of the machinery to improve matters not proving satisfactory, B., following the suggestions of his independent expert adviser, now employs the brickmaking machine by E., in combination with the grinding plant supplied some time previously by D. The result is that

with the altered machinery B.'s plant is now turning out 15 per cent more bricks per day than formerly, and these are stronger and sounder, as well as of a better colour.

As all the machinery in the three cases quoted was of the stiff-plastic type, and by first-class makers, the difference in working can only be explained by differences in the clays worked, and an examination of these showed that whilst A.'s clay is very strong, C.'s clay is very mild, and that used by B. is a boulder-clay and consequently requires treatment quite different from the other two, although it will make bricks of a medium quality when treated by the methods used by A. and C. Elated by his success, B. soon informed his neighbours of the advantage he had gained, and A., having sufficient capital, decided to put in an E. machine. The makers warned him that it was not suitable, and suggested the use of another type of machine of their make, but A. was so convinced by the results produced by B. that, assuming all the responsibility, he installed the machine. The result was a failure, because A.'s clay required such vigorous treatment that it could not be worked up properly in the E. machine. In due course C. followed B.'s example, and, though not so satisfactory as B., still made better goods than formerly, by a combination of machinery from different firms. Yet, inspired by the success of B., A. and C. cannot understand their own failures and do not attribute them to the true cause, but to the machinery makers. The lesson to be learned from these three cases is that owing to the different character of the clays in the same district, it is not wise to argue that a machine made by one firm is necessarily suitable, because it is used by a neighbouring brickmaker.

A good machine of the revolving-table type is shown in fig. 138 and made by Bradley & Craven, Ltd., who claim to have originated this process. It comprises a mixer, a short vertical pug-mill, a circular rotary moulding-table, and an eccentric-motion press. In operation, the clay is carried forward through the mixer (which owing to its position behind the pug-mill is not visible in the illustration) to the pug-mill, from whence, one at a time, each of the sixteen moulds in the rotary table receives a charge of clay. The table remains momentarily stationary while a mould is directly under the operation of the pug-mill, a pugged brick is, during that time, lifted out of another mould on the table and delivered to the press by self-acting gear; this delivery motion to the press pushing forward, for removal by the attendant, a finished brick. The only manual labour required in the forma-

tion of the bricks is for supplying the crude, freshly dug clay either direct to the mixer (when its nature permits of this being done) or, where previous preparation is necessary, to either rollers or to an edge-runner mill (its variety determining the alternative method of treatment). The prepared material being fed into the mixer by self-acting mechanism, one young lad is all that is

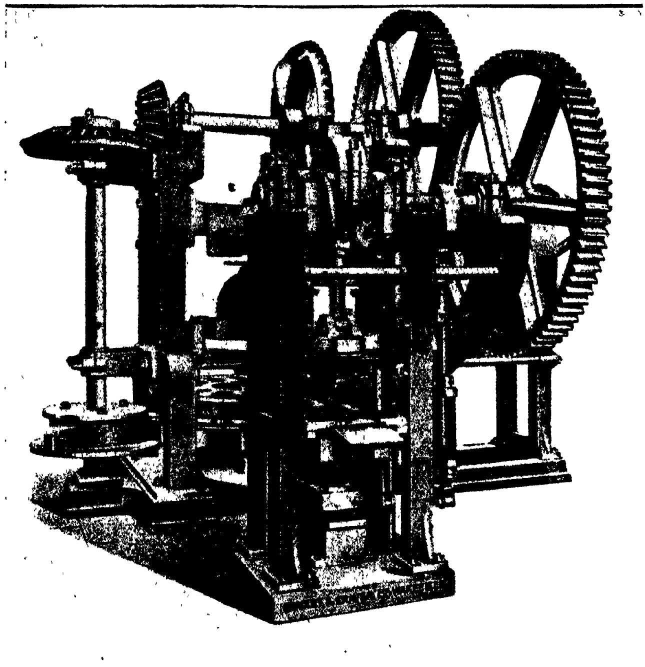


FIG. 138.—Stiff-plastic brick machine with clot-moulds on rotary table.

needed to attend to the mixer, and another to remove the finished bricks from the press to the brick-trucks or barrows.

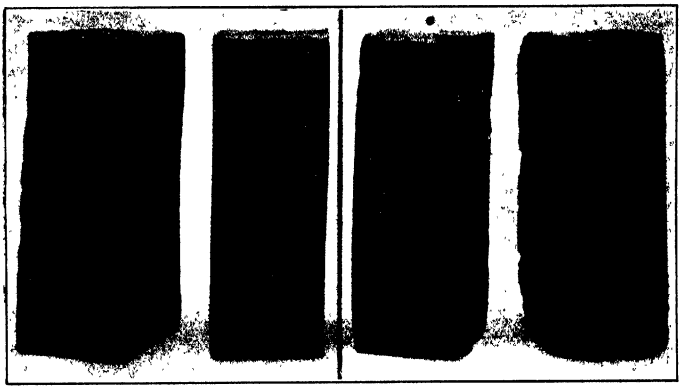
The machine is capable of producing 10,000 to 12,000 bricks per day of ten hours, without the aid of any skilled labour, and the bricks are usually hard enough to go direct to the kiln.

The value of the bricks made by machines of this type depends upon the completeness with which the mould in the rotary table is filled. If this filling is imperfect the brick will be of little worth, as the edges or corners will be of a different

density and hardness to the rest of the brick, and the clot will often show a crack along its bottom edge (fig. 139 A).

Defective filling of the mould is usually due to the employment of too short a pug-mill, or to the absence of a sufficient length of screw or worm on the pug-mill shaft. By increasing the size of this worm any desired compression of the clay within the mould may be reached, and a completely filled die assured. With some clays the addition of an end piece of the shape shown in fig. 140 (designed by Gilbert T. Smith) is sufficient to effect the change shown in fig. 139.

Coring and cracking may often be prevented by the use of a device shown in fig. 141 made by Wootton, Bros., Ltd.



A. B.

FIG. 139.—Clots made with (A) and without (B) end-piece shown in fig. 140.

Sutcliffe, Speakman, & Co., Ltd. (fig. 142), claim to have overcome the principal cause of cracks and badly filled moulds, by arranging the plunger in the clot-moulder to give a resistance to the exit of the clay from the pug-mill into the mould, thus keeping the clay column solid, and preventing it curling up or breaking as it tends to do when delivered into an empty mould. Power is also saved by automatically driving the pug-mill slower when no mould is being filled.

William Johnson & Sons (Leeds), Ltd., make a stiff-plastic machine of the revolving drum-type which comprises a mixer, pug-mill, and a six-mould cylinder, as preliminary moulder and a press.

The mixer and the pug-mill are situated on the same level, and the functions of mixing and pugging are performed by an arrangement of knives fixed on one shaft. The material is delivered first to the mixer and carried forward by the knives to

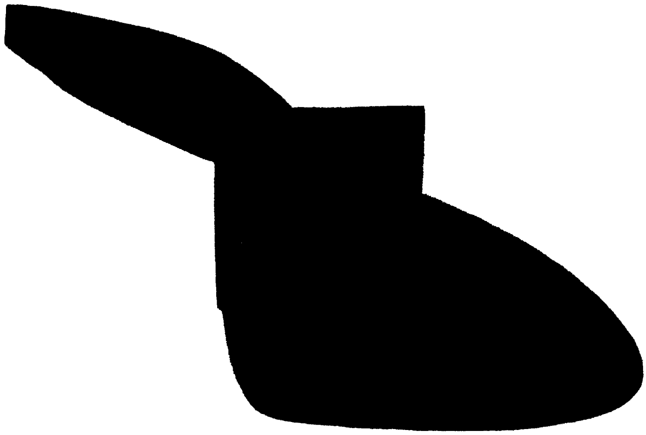


FIG. 140.—End piece for mould filler.

the pug-mill, from whence it is fed into one of the moulds placed at equal distances in a revolving cylinder, about 18 in. diameter. This cylinder remains stationary while the mould is being filled. The action of filling the mould automatically discharges a brick

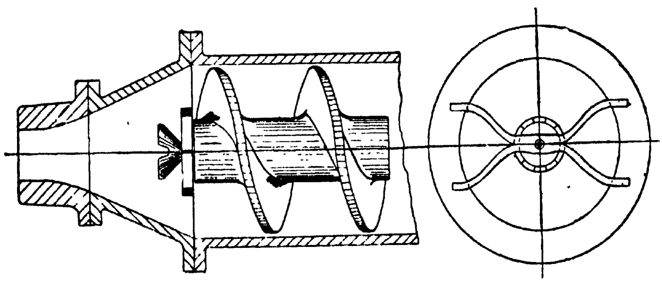


FIG. 141.—Price's patent core preventer.

previously formed from the other end of the drum. As the brick issues from the cylinder it is fed by a self-acting arrangement right into the mould of the press. The pressed brick is then automatically raised out of the press, and is ready to be carried

away. In the similar machine, made by Richard Scholefield

FIG. 142.—Stiff-plastic brick machine with variable speed of pug-mill.

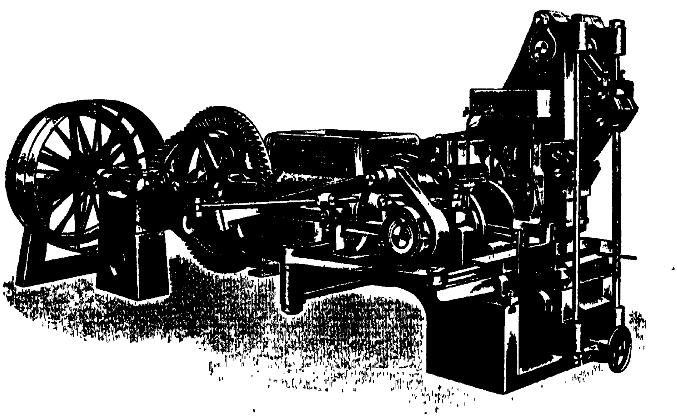


FIG. 143.—Stiff-plastic brick machine with clot-moulds on cylinder.

(fig. 143), the ground clay, or other material, is fed into the

hopper of the machine and is pugged and carried forward by the pug-mill, from whence it is compressed into one of four box-moulds, placed at right angles to one another in a revolving cylinder. This cylinder is stationary whilst being charged, and the action of filling the mould automatically discharges the brick previously formed. The brick, on issuing from the cylinder, is passed forward by a self-acting arrangement into the mould of the toggle press, and after being subjected to two powerful dis-

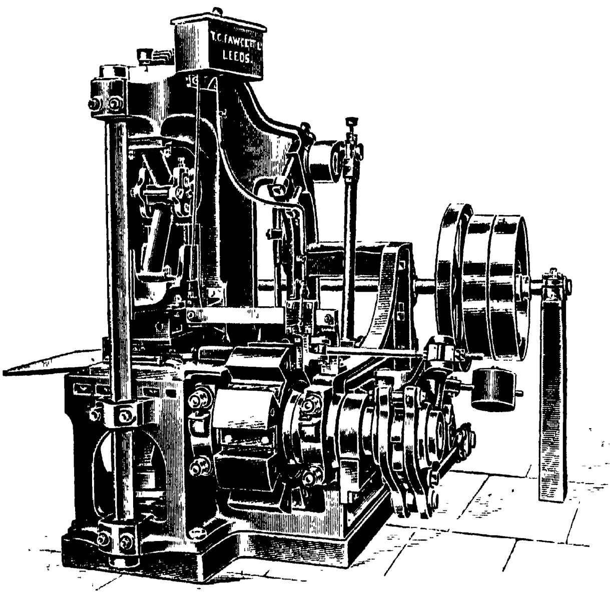


FIG. 144.—Stiff-plastic brick machine with open clot-moulds.

tinct presses, is automatically delivered on to a table ready to be placed on the barrow or trough and taken direct to the dryer or kiln.

A machine of similar type, but in which the drum is open—the clots being moulded in what are practically spaces between the cogs of a large wheel—is shown in fig. 144. The advantages of this arrangement are the reduced number of wearing parts of the mould and the simpler manner in which the moulding drum can be constructed. In this machine, as made by T. C. Fawcett, Ltd., the clay falls down a chute from the screens into a mixer,

where a little water is added, and thence into a pug-mill. After being well pugged it is thrust into a mould in the "cog wheel". At the same time as one mould is filled, the clot in another is pushed out automatically, and sent under a press where it receives its proper shape.

The press is fitted with a hydraulic balance which absolutely prevents breakages. The amount of driving power required by this machine is remarkably low (about 6 b.h.p.), and the bricks produced under normal conditions are of excellent finish and shape, with clean, sharp edges and of great hardness. This machine has in fact been in use for some time for the manu-

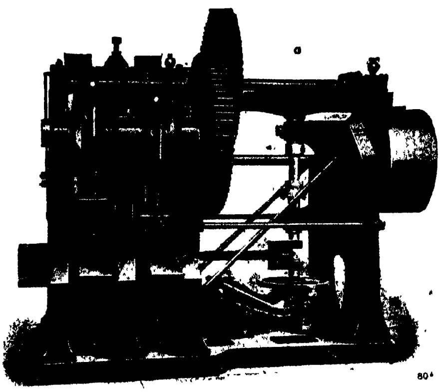


FIG. 145.—"New Era" brick machine.

facture of the highest grades of bricks made by the stiff-plastic process.

Brickmaking machines of the "sliding-die" type are well represented by fig. 142, showing the machine made by Sutcliffe, Speakman, & Co., Ltd., and by the "New Era" machine (fig. 145).

In the machine shown in fig. 142, the chief features are the reduced speed of the pug-mill when not delivering clay into a mould, and the rising of the bottom plunger of the mould in order to create a resistance to the entering clay, and thereby prevent the cracks which are so often noticed in machines where no such resistance occurs. The special construction of the moulds on the "economic" principle (p. 152) facilitates relining.

The "New Era" machine (fig. 145), made by C. Whittaker and

Co., Ltd., is the most recent of stiff-plastic machines. In it the prepared material is fed into a hopper and is discharged into a vertical pug-mill. This pugs the clay and forces it into a clot-forming mould below. There are two of these moulds formed in a sliding block, which brings each mould alternately under the pug. As they are alternately filled, so are they alternately discharged. There are two presses, and the bricks are fed into first one and then the other, one press only being in operation at a time. The makers state that the power used for the two presses is no more than a machine having a single press, but the time of pressing is greater than when a single press is used. The lubrication of the

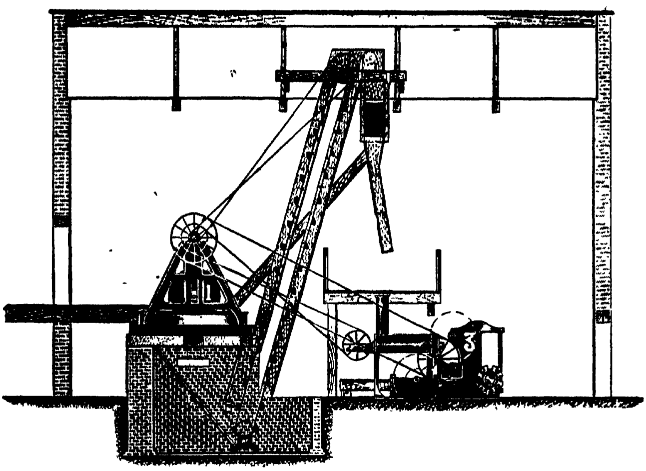


FIG. 146.—Arrangement of plant in stiff-plastic process.

moulds and sliding parts is provided by a simple oil spray, obtained by an air blast from a pressure blower.

The advantage of sliding-die machines is that the clot has a flat top instead of being slightly curved as in drum machines, and the power required to drive them is rather lower than in machines having a rotary table.

A convenient arrangement of the plant for the stiff-plastic process is shown in fig. 146, in which (1) represents the grinding pan, (2) the elevators, and (3) the brickmaking machine; in this instance a Fawcett plant (fig. 144) being shown.

Repressing.—The ordinary product of a stiff-plastic machine can by a little selection be divided into a small proportion of facing bricks and a large proportion of common ones, but when

large quantities of facing bricks are required these should be made by repressing ordinary stiff-plastic bricks immediately they come from the machine, and drying them more carefully than the others so as to secure every possible advantage of form and colour, as well-coloured bricks cannot be produced from undried bricks without an excessive amount of trouble. Bricks may be repressed in any of the machines described as represses on pages 139-153, but the ones employing toggle-levers are in many ways the ones most satisfactory for this purpose in connexion with stiff-plastic bricks. Unlike plastic bricks, those made by

FIG. 147.—Conveyer belt for carrying bricks to repress or barrow.

the stiff-plastic system do not need to be dried previous to repressing, but may be taken direct from the brickmaking machine to the repress. It is, therefore, most convenient to arrange the repress quite close to the brickmaking machine, so that when repressed bricks are required they may be taken automatically from one press to the other, a boy being all that is needed to place them in the box of the repress. In most cases the repress is supplied by the makers of the brick machine and is attached to it. The bricks are then automatically fed into the mould and delivered on to the table ready for removal to the drying shed or kiln. A slide, or better still a conveyer-belt (fig. 147), of sufficient length serves as an excellent bed for holding or con-

veying the bricks from one machine to another when there is much room between them, though usually the repress may be placed close to the machine, and a boy standing between them lifts the brick from the table of the latter and places it in the box of the repress.

The precautions necessary to be observed in repressing bricks are practically the same as those necessary in pressing a brick made from a clot by the stiff-plastic process (p. 198).

Carrying Off.—Stiff-plastic bricks are usually carried to the dryer or kiln on barrows of a pattern similar to the "crowding barrows" used for hand-made bricks (figs. 148-149), or on cars if tunnel-dryers are used.

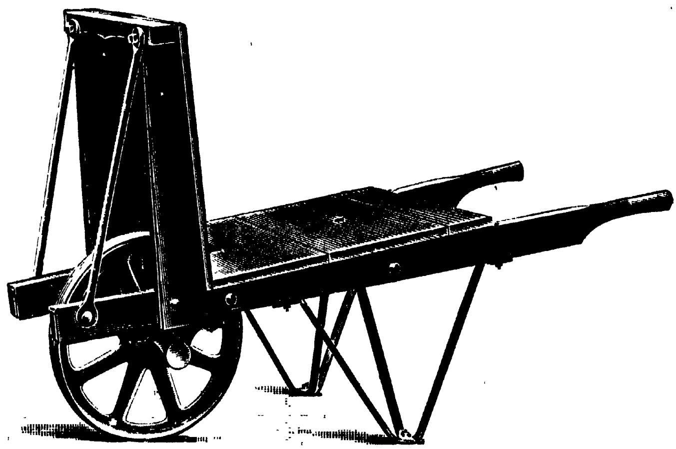


FIG. 148.—"Crowding" barrow.

It is important, in selecting a barrow, to have one in which the relative position of the handles, wheel, and load are correct, as, otherwise, the work involved in their use is greatly increased. To some extent the height of a man influences these factors, and consequently when men do not adhere to their own barrows, no great difference in the height of the wheelers should be permitted. A few trials with a loaded barrow will soon show the correct measurements for a particular man. To secure ease in use, the load should be carried by the wheel of the barrow as far as possible; in a badly constructed barrow, or in one which does not fit the wheeler, too much of the load is on the hands of the man between the shafts. To aid the men and increase the speed

at which they work, the track between the machine or dryer and the kiln should have an iron strip laid for the barrow wheel to run on, and the whole track should be kept in good condition for the men to run on. If muddy and sticky the men cannot travel so fast. The wheelers should be encouraged to *run* with the loaded barrows; it is easier for them, and more remunerative to their employer. Care should also be taken that each barrow is *filled*,

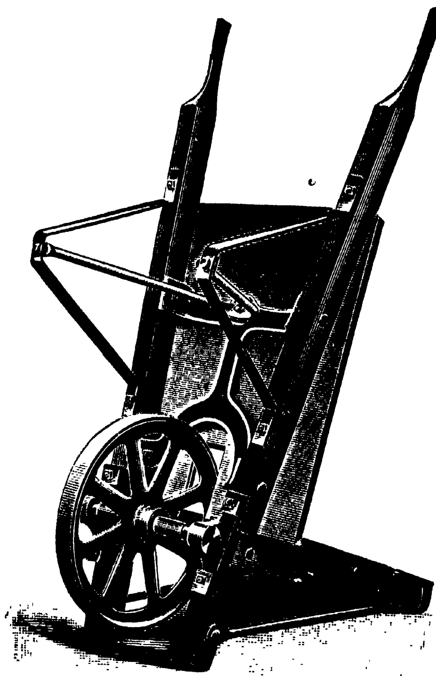


FIG. 149.—Barrow with reinforced frame.

as some men carry too few bricks at a time. A Fawcett "counter" will prevent this. It consists of a recorder fixed to a convenient wall or post and connected by a chain running in a pipe to a balance box, containing a system of balanced levers and placed with its lid level with the ground forming a wheeling plate, one end of which is hinged and the opposite end connected to the levers, which are balanced to the weight of a barrow or wagon of bricks. The wagon or barrow containing the required num-

ber of bricks is wheeled over the lid of the balance box, causing the chain to operate the recorder, and punch a hole in the record disc. The lid then returns to its original position and moves the record disc round a certain distance ready for the next punching, when the operation is repeated. When a full ring of holes has been punched, the punch automatically moves a certain distance towards the centre ready for the next ring. A full disc is sufficient for 29,000 bricks, counting fifty on a barrow. The number of bricks made may be seen at a glance

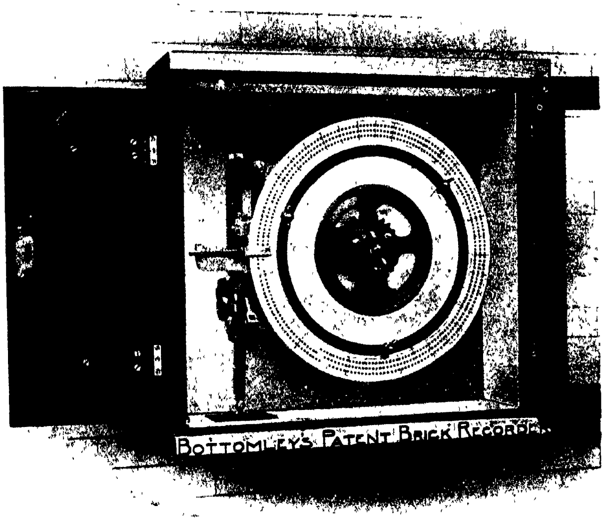


FIG. 150.—Counter made by Thos. C. Fawcett, Ltd.

at any part of the day. It is impossible for any unauthorized person to interfere with the working parts without the tampering being detected, and it thus forms a positive method of counting the bricks.

Barrows are convenient, but the carrying off is facilitated, where there is sufficient room, by employing a short belt running horizontally (fig. 147), for taking bricks from the table of the press or machine and delivering them several feet away to the men with the barrows, or a long belt may sometimes be used to deliver the bricks direct to the drying sheds or kiln.

Instead of a belt, two ropes may be driven parallel to each other, and bricks on pallet boards laid across these will then be carried forward to their destination. This arrangement is especially useful where the bricks are taken direct from a cutting table. The empty boards are placed on the lower part of the rope and a permanent scraper throws them off directly they arrive at the machine.

Where the relative position of the machine or dryer and the kiln permits, a belt or conveyer may advantageously be used in setting. One pulley or spool is taken inside the portion of the kiln to be set and is slung up by means of a chain attached to the roof or, through a pot-hole, to a bar above the kiln. The other end is in the dryer or making shop. In this way the bricks are delivered direct to the setters, just as they are required. This method is increasing rapidly in popularity in the United States, where it is worked under Scott's patents.

Another method, also largely used in America, consists in setting the bricks out on a special carrier exactly as they are to be placed in the kiln. This carrier is then taken by means of an overhead ropeway to the kiln, and by a simple motion the bricks are set and the empty carrier returned. For large outputs with kilns of the "improved clamp" type, this arrangement is good, as it saves handling, but the author has not found it so satisfactory in continuous kilns of the Hoffman type.

Drying.—According to the amount of moisture in the bricks, the size of the solid particles, and the kiln in which firing takes place, the bricks may be taken to a dryer or direct to the kiln. In most instances where a continuous kiln of good type with at least sixteen chambers is used, the bricks need not be dried separately, but may be set in the kiln and the drying allowed to take place therein. With single kilns, or where continuous kilns with few chambers are employed, it is usually necessary to dry the bricks before setting them in the kiln. Such drying is also necessary where the bricks have a strong tendency to scum, and where it is difficult to obtain a good colour.

Any of the dryers described in Chapter IV as suitable for bricks made by the plastic process may be used, but as stiff-plastic bricks contain less moisture they shrink less, and may, therefore, be dried more rapidly. Being stronger on account of their stiffness, they are specially adapted for treatment in tunnel-dryers of the "direct type," in which the bricks and air travel in the same direction and are both heated progressively.

Failing a suitable tunnel-dryer, they should be stacked about eight bricks high in a shed with a heated floor (p. 156). If such a shed has partitions or blinds, so as to separate it into a number of tunnels and to enable the temperature in each section to be regulated so as to suit the bricks in it, the drying will be better and more economically carried out than where the usual "open shed" is used. Ventilation must be provided, but draughts on the bricks avoided.

A simple and cheap dryer of the intermittent form has been patented by W. B. Hughes, and consists of skeleton timber framing fixed upon a brick curb with adjustable sides, which, when removed, give easy access for taking the bricks on the ordinary off-bearing barrow. As the sections are filled, the boards forming the sides are put into position and the dryer started working. When the bricks are dry the side boards are taken out, giving free access for the barrows.

The heat is obtained by means of 3 in. cast-iron pipes, to which either live or exhaust steam is connected. A fan is used for forcing hot air at any desired temperature up between the already heated cast-iron pipes and through the goods to be dried. Such a dryer is cheap to construct, requires little attention, and is easily built, but has the disadvantage that the bricks must be stacked in it instead of being left in the cars as in other tunnel-dryers.

The same principle is used extensively in the United States in what is known as the Bechtel dryer. The floor of this dryer is in the form of a number of trenches, the walls of which are sufficiently wide to allow a special barrow (fig. 151) to travel along them. After the barrow has been wheeled into position the handles are raised, and the pallet-boards containing the bricks are deposited across the trench and the empty barrow can then be wheeled away. The bricks are set in a series of blades the whole length of the dryer, and when one trench is completely covered with bricks from end to end they are covered with special burlap coverings (fig. 152), so that as soon as the heated air commences to extract the moisture from the drying bricks, instead of it being immediately dissipated into the dryer, this hot saturated air is largely retained on the outer surfaces of the bricks by means of these coverings, and so long as this state of humidity is maintained, the brick dries from the inside outwards, the surrounding moisture preventing the hardening of the surfaces of the brick and obviating "checking". In other words the out-

side of the brick dries last. This is an important advantage, especially where clays are of a tender nature. A fan is used for supplying the hot air to the flues.

One of the most novel forms of dryer at present in use is that worked under A. Scott's patents, in connexion with a kiln of the horizontal draught or archless continuous type. This system is the most radical departure in drying methods yet introduced. It boldly does away with not only cars, rails, pallets, and other incidental apparatus, but with the dryer itself!

The system consists of two factors: First a belt conveyer to

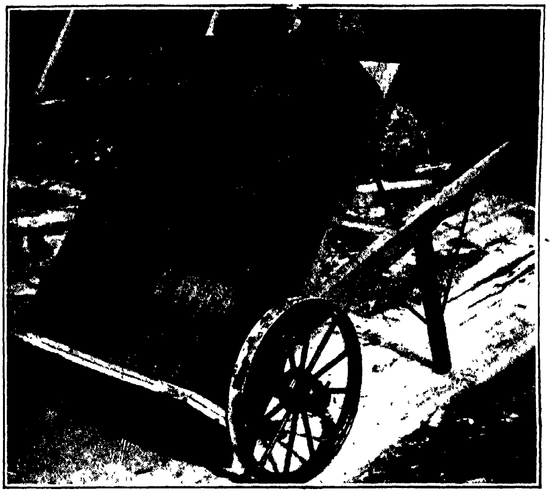


FIG. 151.—Bechtel barrow.

take the bricks from the machine up to and into the kilns; second, the drying of the bricks in the kiln after they are set. The system is, of course, specially adapted to the handling of "stiff-plastic" and "semi-dry" bricks. For bricks made by the plastic process it is not advantageous. The main conveyer takes the place of the ordinary off-bearing belt of the brick machine. It receives the bricks from the cutting table and carries them down the yard under a shed built along in front of the line of kilns. When the bricks arrive on this belt opposite the kiln into which they are to be set, they are transferred, by a man stationed at this junction point, to another belt which extends through the kiln.

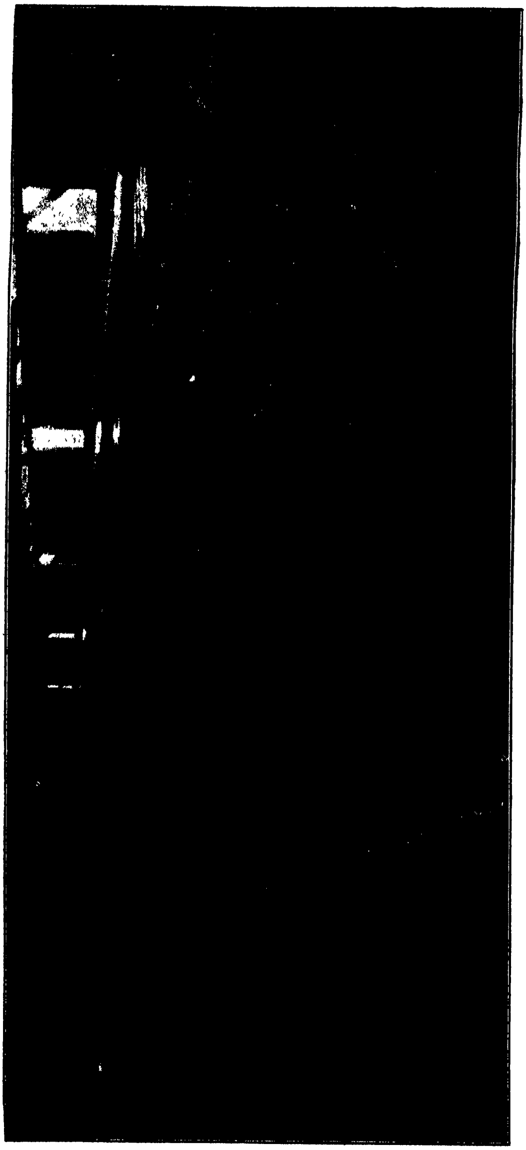


FIG. 152.—Bechtel Dryer showing trench and covered bricks.

This work of transferring is accomplished by one man, who can handle from 60,000 to 70,000 bricks daily. The cross-conveyer, as this second belt is called, carries the bricks into the kiln at any height desired to ensure the efficiency of the setting. The bricks are generally set from six to eight high. When the entire kiln floor has been set to this height the cross-conveyer is raised to the proper height for the next setting, and the setters proceed to another kiln or chamber to continue the operation, while these eight courses of brick are being dried. The object being to dry these sufficiently for the next twelve hours to support the setting of the next eight courses. When these are dried the next tier is set and that again dried, the operation being repeated until the entire kiln is filled and ready for burning. The burning is carried on in the usual manner. It is claimed that when the top tier of bricks is dry, the bottom course is as hot as the heated air will make it, and the kiln is in a perfect condition to start firing without water-smoking.

The drying of the bricks in the kiln is accomplished chiefly by the application of waste heat. It is maintained that the saving on fuel and labour costs amounts to about 2s. 6d. per 1000, due to the fact that the bricks are drier than those turned out from the ordinary dryer, and that the kiln is hot when the fires are started, so that the water-smoking cost is reduced to a minimum. The method requires considerable adaptation before it can be used for most British yards. In the United States, where it is chiefly used, large kilns with open tops ("scove kilns") are chiefly used for common bricks, and for these this system is excellent.

Kilns.—Bricks made by the stiff-plastic process may be fired in single or continuous kilns, the latter having the advantage of using less fuel, and at the same time giving bricks of equally good colour if properly constructed and managed.

Of the single kilns, the "down-draught" and "Newcastle" types are usually best, but others are used to the satisfaction of various brickmakers.

Where the output is large, a continuous kiln is undoubtedly the most suitable, as if properly designed for the purpose it can receive the bricks direct from the machine and dispense with a dryer. Where only common bricks (with or without a small proportion of facings) are to be made, a continuous or semi-continuous kiln should be used. These are described in Chapter VIII.

The preliminary heating of bricks made by the stiff-plastic process should be effected with special care. If this precaution is duly observed, the firing of bricks made in this manner presents no difficulties not met with in other methods of brickmaking.

CHAPTER VI.

THE SEMI-DRY OR SEMI-PLASTIC PROCESS OF BRICK-MAKING.

In the semi-dry or semi-plastic process the clay is used in its natural condition, no weathering or other treatment being used (except in special cases) to develop the plasticity. Both terms "semi-dry" and "semi-plastic" are used for the same process, though the former is better and clearer, as well as less likely to be confused with the "stiff-plastic" process in which a small amount of water is needed. The semi-dry process has the advantage of remarkable cheapness in working, as the bricks can be sent direct to the kiln, but it is not so popular now as formerly, because of the introduction of the stiff-plastic system, and of the greater ease with which the stiff-plastic bricks are sold to builders.

Owing to the dryness of the material, the semi-dry process can be used in many instances where other processes are not so suitable, but the bricks produced from this material are seldom so satisfactory as those made from more plastic clays. The greater cheapness of producing semi-dry bricks is very much in their favour in certain districts (notably in the neighbourhoods of Peterborough and Accrington) and this process will, therefore, hold its own in some localities for a considerable time to come; indeed, for the special clays found in certain parts of Lancashire (Accrington), and near Fletton (Peterborough), it is difficult to conceive a process by which bricks of saleable quality can be produced more cheaply than when made by the semi-dry process.

The most suitable clays for the semi-dry process are those of a lean or open character; highly plastic-clays cannot be used, and several attempts to employ them have only resulted in failure, as they require more thorough treatment than is possible when they are worked up in a semi-dry state. The ideal clay for the semi-dry process is one which, when ground, balls together when squeezed in the hand without losing its shape when the

pressure is removed and yet which does not feel sticky or plastic. It must also contain sufficient flux to bind the particles together into good bricks when fired at a reasonable temperature. The clay must be free from gross impurities, and if not regular in composition, some arrangement must be made for mixing it thoroughly, as irregularities in this respect will cause failures which it is often difficult to trace to their source. Many *shales* are capable of being efficiently worked by this process.

The use of semi-dry process machines has been pushed vigorously during recent years, but it would be unwise to install them on new and untried clays unless precisely similar materials had been successfully worked by this system, or unless the brickmaker is willing to experiment on a very large scale, as this is one of the most difficult of brickmaking processes to put into satisfactory operation, and the most prominent users of it have only attained their success as the result of incessant labour of a highly skilled character.

In the semi-dry or semi-plastic process of brickmaking the clay is dug from the pit, sent in wagons to a grinding mill of the edge-runner type, and the ground material is subjected to the action of powerful presses, which form it into bricks. These bricks are taken direct to the kiln.

The following is the arrangement of plant used by the London Brick Co., Ltd., of Fletton, Peterborough, one of the largest manufacturers of bricks by this process:—

Early investigations having proved the necessity of mixing the different strata (including an oily shale) found in the Fletton bed, steam navvies are used to take a scrape right up the whole face of clay and ensure a good proportion of each stratum. As in this district the topmost layer of earth (or "callow") is not suitable for treatment, it is removed by a preliminary steam navvy and taken along a belt conveyer to a place where it may conveniently be deposited.

The steam navvies used for obtaining clay in this manner are of the type shown in fig. 153, and are so constructed that when the bucket or grab is filled with clay it is swung round, and after opening a door at the back of the bucket, its contents are discharged into a wagon. The bucket is provided with steel claws which break up the ground, and about 1 cub. yd. of material is obtained at each stroke of the machine. With such an appliance, and working under favourable conditions, it is easily possible to cut up a face of clay and load it into wagons

at a cost of about twopence per cub. yd. As the wagons are filled they are hauled by an endless chain to the mills.

For the most part the grinding is carried out in edge-runner mills, though in a few cases disintegrators and stone-breakers have been used, but these do not, on the whole, produce the desired results. The most suitable mills are those of the revolving dry pan type (p. 183), as the material must be reduced to a fine powder.

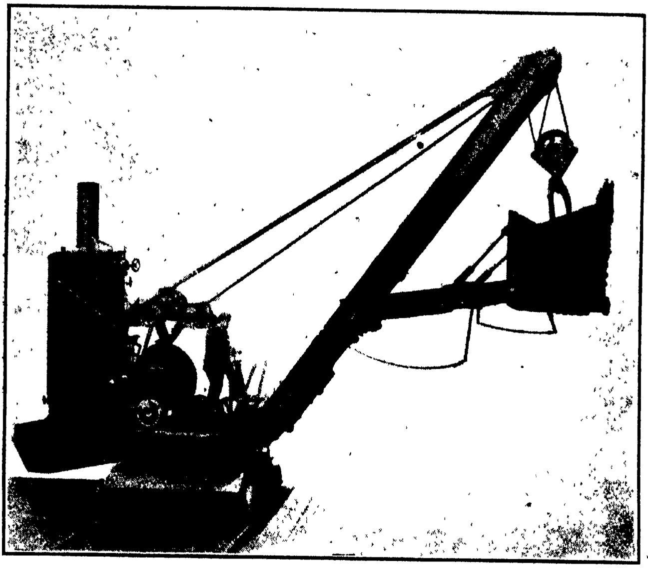


FIG. 153.—Steam navvy (Ruston-Proctor & Co.).

The crushed material is next taken to the screens by spiral conveyers (figs. 154 and 155) which assist in mixing it thoroughly, though other forms of conveyers may be substituted, provided that a special dry mixer is included at a later stage.

The screens used by the London Brick Co. are of the "piano-wire" type (p. 194), this having been invented by their manager, Mr. A. Adams; but some other firms have found perforated steel plates to be more efficient. This is clearly a matter for each brickmaker to decide for himself, as so much depends on the nature of the material used. The objection to piano-wire screens as ordinarily supplied is that the larger por-

tions of material are apt to lodge between the wires, parting them and making the screens ineffective. This may be overcome by using two screens, providing the material is not too lamellar in structure.

The material which passes through the screens is received in a hopper or on to a floor, from whence it passes down a chute to the machines; but the material which is too large to pass the screen is sent down another chute to the grinding mill for further treatment.

The screened dust must possess sufficient dampness before it

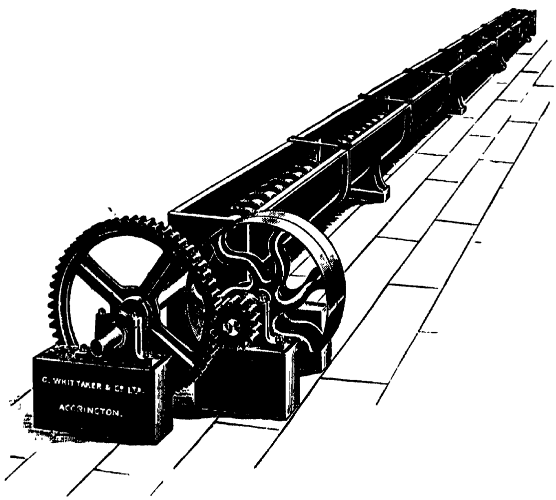


FIG. 154.—Spiral conveyer.

is allowed to pass into the brickmaking machine. It should be able to be pressed by the hand into a ball; if too dry it will not hold together, and will necessitate the addition of water to the clay in the grinding mill or mixer. In some cases enough water may be present in the clay, though very unevenly distributed, so that some parts are dry and will not hold together, the material must then be passed through extra mixing machinery.

In the brickmaking machine, the material is pressed into a block and, if desired, repressed and sent to the kiln. The London Brick Co., Ltd., have found that four distinct pressures are necessary to obtain the best results.

The presses employed by the London Brick Co. are made

by C. Whittaker & Co., Ltd., illustrated in fig. 156. The ground material from the mill and mixers is fed into the hopper of this machine, and thence by means of a sliding box into the first mould. The amount of material received in the mould can be regulated instantly, so that as the dampness of the material varies from time to time more or less clay can be taken into the mould. The brick, after having two pressures put on to it, is automatically fed into the second mould and there it is pressed twice more; thus it is subjected to four distinct pressures, each pressure being about 80 tons. This machine has an output of 5000 to 6000 bricks per day, and, according to the makers, requires 5 h.p. to drive it. It should be noted that in this machine no oil is used to lubricate the moulds.

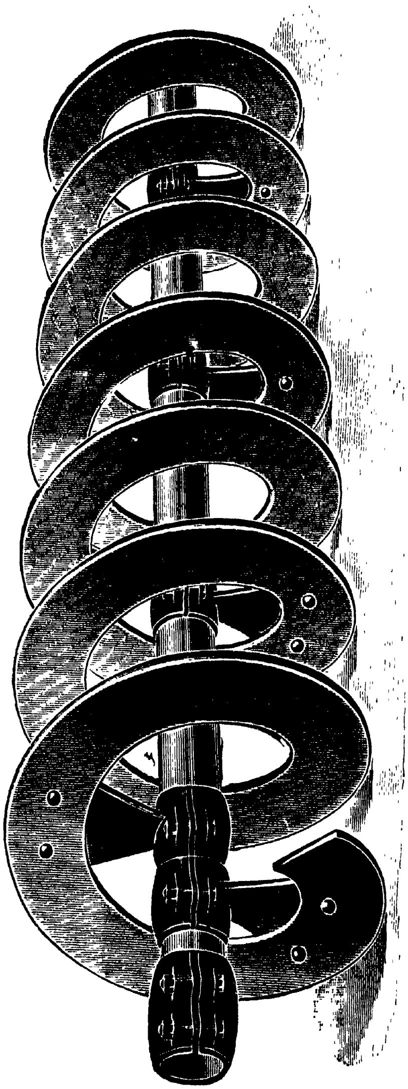


Fig. 155.—Worm of spiral conveyer.

After leaving this machine the bricks are taken straight to

the kiln, which, in the case of the London Brick Co., is a continuous one of exceptional size and designed in a special manner rendered necessary by the proportion of oil and other combustible matter in the clay used. This kiln (known as the " English ") is described in Chapter VIII.

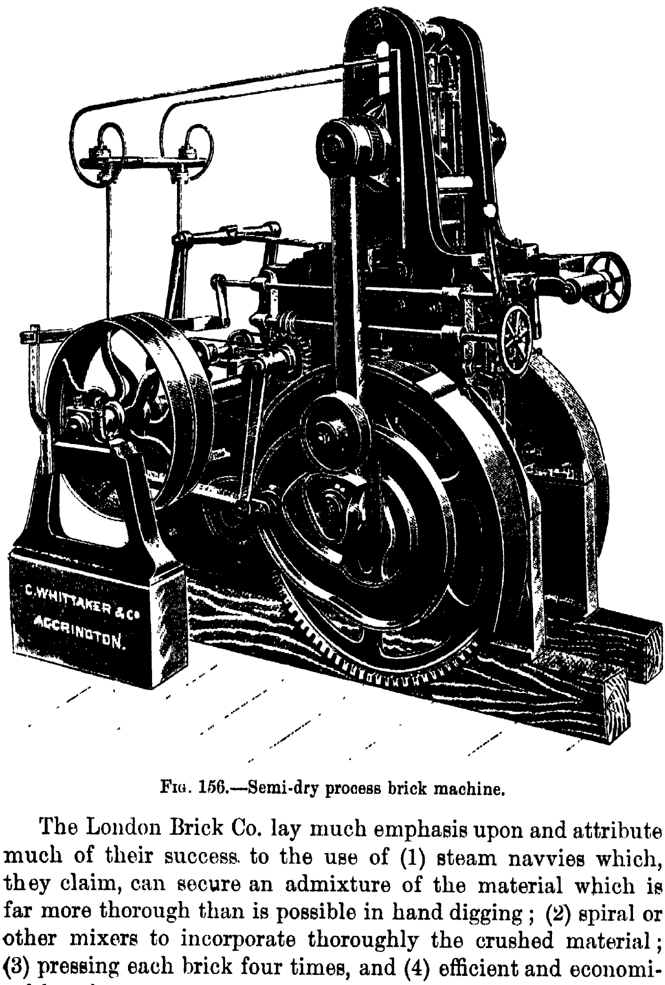


FIG. 156.—Semi-dry process brick machine.

The London Brick Co. lay much emphasis upon and attribute much of their success to the use of (1) steam navvies which, they claim, can secure an admixture of the material which is far more thorough than is possible in hand digging ; (2) spiral or other mixers to incorporate thoroughly the crushed material ; (3) pressing each brick four times, and (4) efficient and economical burning.

It is undoubtedly true that the cracked faces, liability to spall, and other defects of many bricks made by the semi-plastic process is due to an insufficient recognition of the importance of the material being thoroughly homogeneous and sufficiently pressed.

Machines for making bricks by the semi-dry process are also supplied by other firms. The arrangement of plant shown in fig. 157 has been used successfully in several instances by Thos. C. Fawcett, Ltd.

In this plant the material is ground in an open base revolving pan mill (p. 188), and taken by a bucket elevator to a "Neway-ago" (p. 194) or other suitable screen. The finer portions of material are then passed through a double differential mixer similar to that shown in fig. 158 where water is added (if necessary) to bring the material to the proper consistency. The mixture is then delivered to the press shown in fig. 159, which is in many respects similar to the Fawcett duplex press used for the stiff-plastic process. In this machine the damp powder is rammed into a clot in open-ended moulds forming the cogs of a special wheel, and each clot is in turn fed into the box of a toggle-lever press where it receives two distinct pressures. This produces a brick which is, in most cases, sufficiently dense and ready to set directly into the kiln.

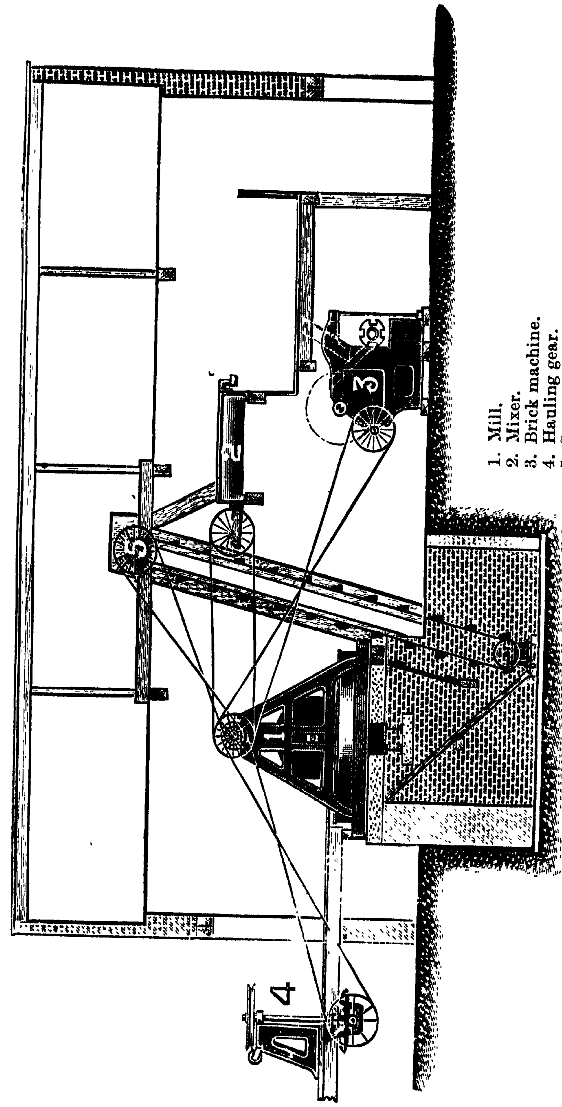
For best facing bricks, however, the use of a repress (fig. 160) is desirable, particularly if this has an attachment for regulating the thickness of each brick.

Such a plant as this has an output of 10,000 bricks per day and requires 20 to 25 b.h.p. to drive it under normal conditions.

The machine made by Rd. Scholefield is identical in principle with the Fawcett plant, but differs in several important details. Thus, the moulds have closed instead of open ends, and instead of an arm pushing the clot out of the press wheel, or drum, in the Scholefield machine it is pushed out by the filling of the opposite portion of the drum preparatory to making a new clot. This "Sanspareil" machine is shown in fig. 161.

The efficiency of the machine has recently been enhanced by the introduction of an adjustable feed, which, without stopping the machine, can be regulated to feed a greater or lesser quantity of clay into the moulding cylinder, thus preventing an excessive escape of clay and consequent loss of driving power and assuring a full feed.

The centre and bottom joint of the toggles are of special



1. Mill.
2. Mixer.
3. Brick machine.
4. Hauling gear.
5. Screen and elevator.

Fig. 157.—Arrangement of plant for semi-dry process.

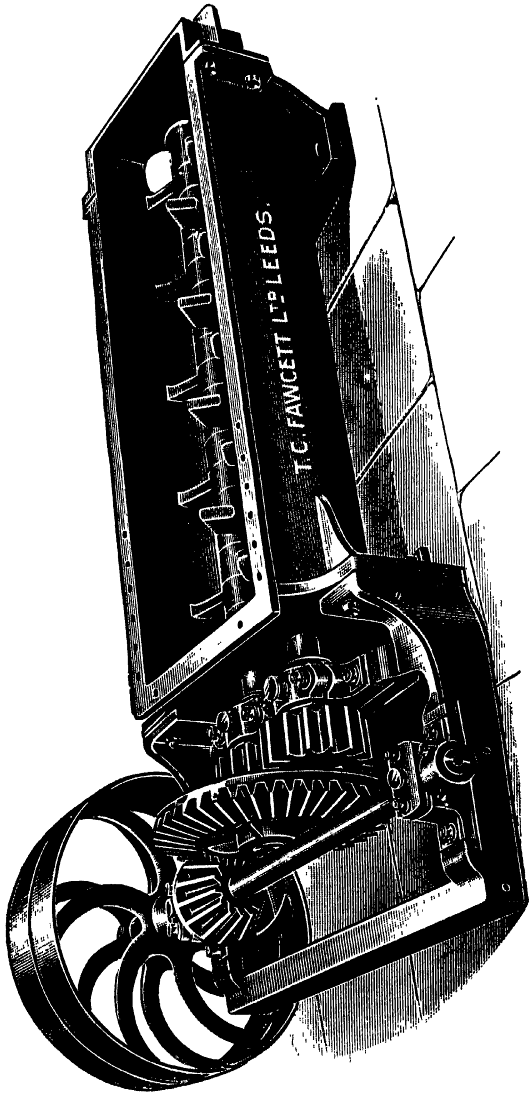


FIG. 158.—Double differential mixer.

design in the form of "knuckles" dispensing with the usual joint (which is formed by a pin or shaft passing through holes bored in the respective ends of the toggles. These "knuckles," which are easily adjustable, have extra large wearing surfaces, are machined to fit the steel cups or sockets, bored out to receive them, and are also arranged in such a manner that it is equally simple to subject the brick to two exactly equal pressures, or to a heavy first pressure and a second

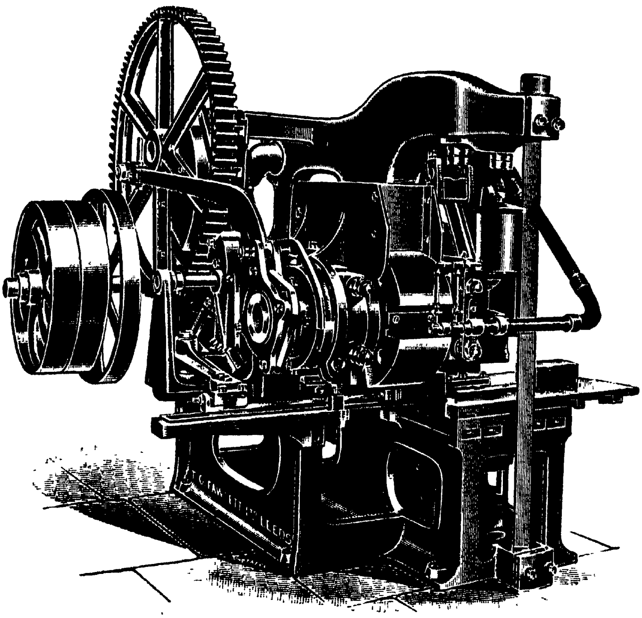


FIG. 159.—Semi-dry process brick machine.

light pressure, or to a light first pressure and a heavy second pressure, with one revolution of the crank-shaft. After the first pressure has been brought to bear upon the brick, it is released for a short space, after which the second or final pressure is applied, and the brick is automatically discharged from the press mould on to the delivery table. The thickness of the repressed brick can be regulated accurately by means of a "folding wedge" adjustable pressure block, without stopping the machine.

Wm. Johnson & Sons, Ltd., Leeds, have for a number of years

manufactured the semi-dry press shown in fig. 162. The powdered material is fed into a hopper, which is part of the

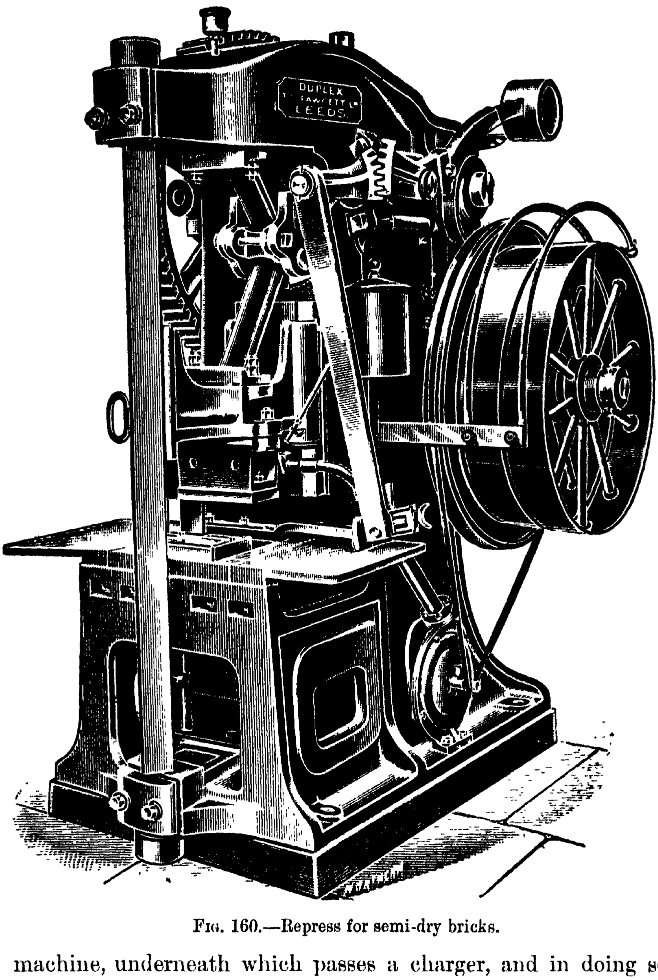


FIG. 160.—Repress for semi-dry bricks.

machine, underneath which passes a charger, and in doing so becomes filled with ground clay. After this the charger passes over the mould, drops the material into the latter, and then returns to the hopper for a fresh charge of clay. During this

time the brick is pressed in the mould by a descending plunger and also an ascending one underneath, these being operated by a powerful cam and anti-friction roller so that the brick receives the pressure simultaneously both from the top and bottom. This ensures a uniform pressure over the whole brick. The pressure can be varied in a very simple manner by the attendant, who also loads the bricks on to a barrow or cars ready for removal to the kiln.

This machine has a daily output of 7000 bricks and, on the maker's statement, needs about 6 h.p. for driving it.

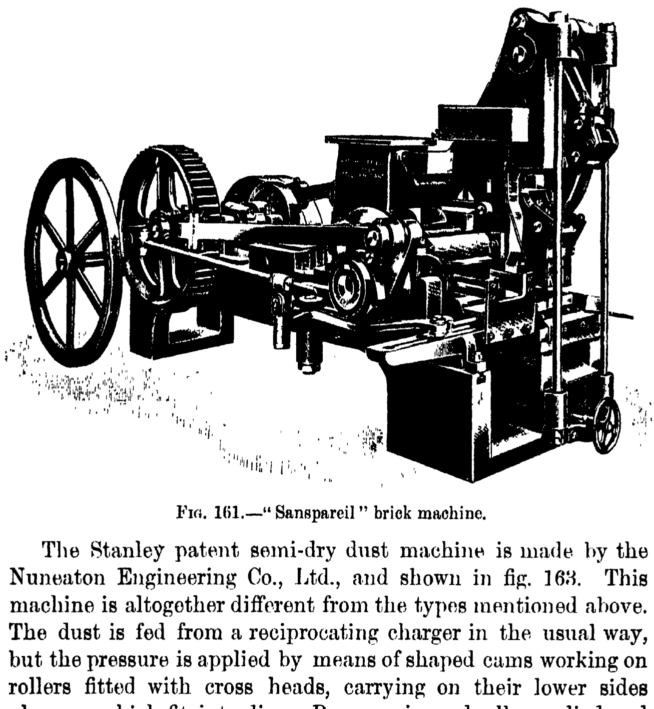


FIG. 161.—"Sanspareil" brick machine.

The Stanley patent semi-dry dust machine is made by the Nuneaton Engineering Co., Ltd., and shown in fig. 163. This machine is altogether different from the types mentioned above. The dust is fed from a reciprocating charger in the usual way, but the pressure is applied by means of shaped cams working on rollers fitted with cross heads, carrying on their lower sides plungers which fit into dies. Pressure is gradually applied and during the process is slightly relieved, allowing the escape of air and the equal expansion of the clay dust in the die. At the finish of the pressing stage the top plungers and dies are forced down on to the stationary bottom plungers, regulated to a greater or lesser degree as required. This simple action gives the bottom,

sides, and arrises as true and hard a finish as the upper parts of

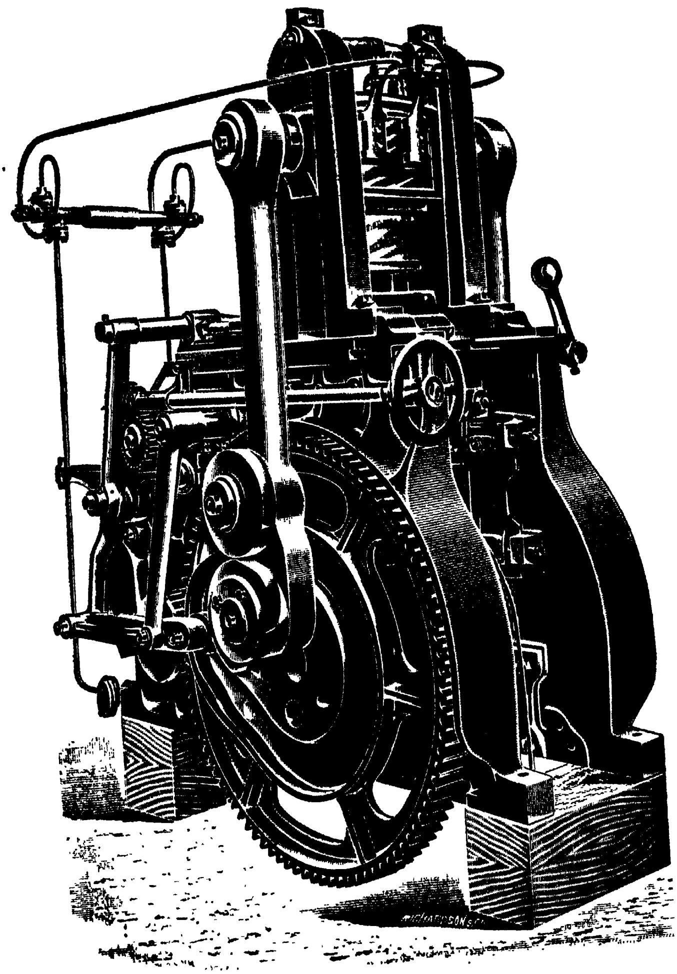


FIG. 162.—Johnson's press for semi-dry process.

the brick. As the feed-boxes fill the dies they deliver the pressed

bricks to the front, giving ample time for the attendant to remove them.

The advantage of receiving such a second pressure on the lower part of the brick is very great. Machines which only give a single direct pressure usually leave the centre of the brick coarse and weak. The extra movement of the Stanley machine prevents this weakness.

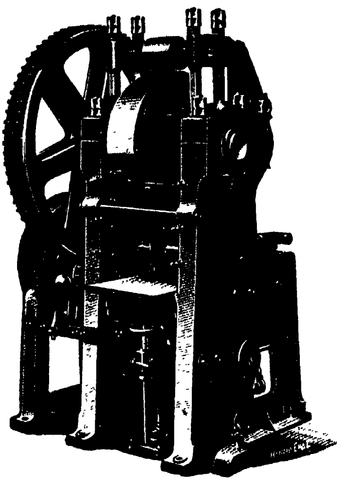


FIG. 163.—Stanley press for semi-dry bricks.

The clay is kept in motion when under pressure, and the contact with the sides of the mould causes the sides of the brick to be thoroughly smoothed and free from signs of granulation, though whether granulation is really removed or only covered over is a moot point with some clays.

In its latest form the machine is fitted with two die boxes and plungers so as to make two bricks at once, and with lifting fingers which raise the brick and carry it forward to the delivery table, where it is placed down gently and the fingers travel back to receive a second brick. This arrangement preserves the arrises from the damage which is inevitable when the bricks are pushed along to the delivery table.

The machine is also fitted with a special charging appliance which takes the form of a false bottom in the feed box which supplies the clay to the die. In the ordinary form of feed there is an unavoidable tendency to produce bricks with one soft end, owing to the manner in which the clay is fed into the die. In the new arrangement the false bottom is closed until the box is completely over the die, when it opens from the centre outwards, fills the die with the dust, closes and carries the box out of the way of the descending plunger.

Amongst other machines using cam rollers may be mentioned the "Platt" machine (figs. 164 and 165), which has a falling cross head carrying the piston and gives a hammer-like action to the

material under pressure, through the head dropping twice in each revolution. The first drop displaces the air, which escapes when the cross head is raised, and the second drop, followed by the enormous pressure of both upper and lower cams, produces a very

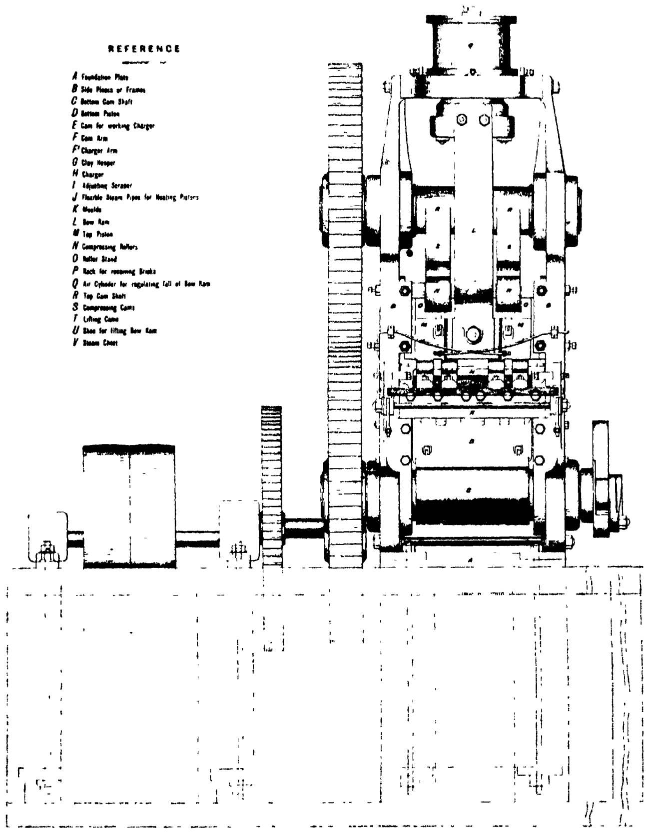


FIG. 164.—Platt Bros. & Co., Ltd., press (front view).

dense brick. An air-cylinder is placed at the upper part of the press to regulate the speed of the falling plungers.

A press of an entirely different type is the "Emperor" made by Sutcliffe, Speakman & Co., Ltd. (fig. 166). Though primarily designed for materials devoid of plasticity, this press is well suited for some clays worked in a dry or semi-dry state.

It consists of a horizontal, rotating table containing the moulds arranged singly or in pairs, and, depending on the size, there are from six to eight pairs of moulds. The table is rotated in such a manner that whilst one pair is receiving the charge of material to be pressed, another is under pressure and a third is over the discharge ram. The feeding is quite automatic, being effected by means of a circular pan in which revolves a series of stirrers which prevent the material choking, and ensure a regular and constant feed. The quantity of material fed into the moulds is regulated by means of a hand wheel, and, as this can be turned whilst the machine is in motion, the pressure can be regulated at will. The pressing mechanism is of the toggle and knee type, and the distribution of the pressure

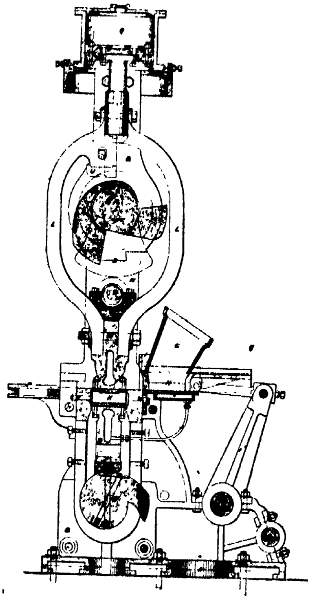


FIG. 165.—Platt Bros. & Co., Ltd., press (side view).

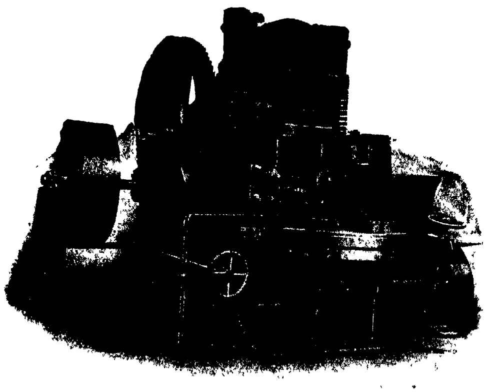


FIG. 166.—"Emperor" press.

is so effected that massive steel bolts take all the greater strains

of the framework. Ample adjustments are made for taking up wear and tear. The moulds are on the "economic" principle (p. 152) and are easily relined, as in putting in new liners no fitting or adjusting is required. Each set of liners can be reversed, giving two wearing faces.

FIG. 167.—Action of "Emperor" press.

This press can be made to give a top and bottom equal and imultaneous pressure, or to give a bottom pressure only, or a uadruple pressure, the final pressure being greater than the irst.

A patent expression attachment (fig. 167) operates by giving ach brick two pressings, the first squeezes and presses the aterial from the centre into the corners and arrises, the final ressure finishes the brick. By these means each brick is of even

density throughout, with fine sharp corners and arrises. In fig 167 "A" shows the mould receiving the first preliminary pressure and "B" the final pressure.

When used for brickmaking the goods are delivered on the table for removal by the attendant, and are not pushed from the moulds, as in presses of the vertical type, but an automatic pusher-off can be attached to the machine to deliver the bricks on to a travelling band if desired.

This machine has a maximum output from 1000 (single type) to 2400 (duplex type) bricks per hour. The power required to operate it is from 5 to 12 h.p. It works smoothly and easily, and owing to powerful springs shown in the illustration, it is evenly balanced. These springs are not for relieving the pressure, but merely to balance the heavy pressing mechanism and, if desired, the machine can be run without them.

The "Emperor" press has deservedly made a great reputation for itself for working all kinds and qualities of non-plastic or slightly plastic material, including ores of all descriptions, artificial fuels and sands, iron and steel slags, destructor clinker, coral rock, puzzolana, and cement mixtures as well as clay.

Repressing.—As the solidity of the unfired bricks is chiefly due to the pressure to which they have been subject, it is important that this should be sufficient, and whilst some firms prefer to press the bricks only once, a second pressing should not be omitted where the best and strongest bricks are required. As already stated, the best machines subject the bricks automatically to two or more pressings, thereby avoiding the necessity of repressing.

Transport.—In most instances pressed bricks are taken on crowding barrows (fig. 148), and are wheeled along iron strips to the kiln. In a few works they are loaded on to double deck cars (p. 171) and taken along rails, turn-tables, and portable rails inside the kiln.

Kilns.—Any good type of kiln may be used, but as the semi-dry method is chiefly used for large outputs, some form of continuous kiln is to be preferred. Details of these will be found in Chapter VIII.

Difficulties in Working. The difficulties met with in working clays by the semi-dry method are similar to those met with in working the stiff-plastic process, but the weakness caused by lamination is much more frequent; indeed, it is the great bugbear of the maker of this kind of brick.

Lamination is recognized by the production of thin layers of material, easily visible when a brick is broken, which cause the brick to split off or spall in certain directions. It is not often due to insufficient pressure, but may be caused by excessive pressure if this is applied at the wrong time.

In many instances the cause of lamination is very obscure, but insufficient treatment of the material is a prominent factor, especially if the clay is obtained dry and is damped and imperfectly mixed later. This produces portions of material in which the plasticity is strongly developed, whilst in others it is scarcely developed at all, and lamination consequently results. One brickmaker of the author's acquaintance has compared it to the use of flour in preparing puff-pastry. "The dough is rolled out into thin pieces, and sprinkled with flour and then rolled again. On placing in the oven, the dry flour causes the plastic layers of dough to part from each other, and the laminated character of puff-pastry is thereby obtained."

The manner in which the pressure is applied is very important for, as pointed out by Lovejoy, it is important to remember that on any machine in which the plungers approach each other and squeeze the clay toward the centre of the mould, the brick will show a comparative granulation on this centre plane, due to a lack of density, quite noticeable even at some distance. "If the pressure is all from the top, the granulation will be at the bottom, and its position will depend upon the relative degree of motion of the two plungers. This granulation is often attributed to included air, and all machine manufacturers provide for its escape, either through air holes in the plunger plates or by releasing the pressure before the final pressure is applied. But, admitting the effect of the included air and the desirability of allowing it to escape, it is not sufficient to account for the granulated surfaces obtained in practice.

"Dry or semi-dry clay will not flow under pressure. If a tube punctured with holes from top to bottom to allow the escape of the included air be filled with dry clay, and pressure be applied at the top, a column of clay is obtained decreasing in density from top to bottom, due to the friction against the walls of the tube and the immobility of the clay.

"In a press with roller cam motion the clay is most compressed at the top, and least at bottom during the downward stroke, with the reverse during the upward stroke. The loosely packed clay in the bottom offers little resistance to being forced down-

ward in the mould, whilst the densely packed top offers great resistance to being forced upward during the upward stroke, to the advantage of the bottom of the brick in density. From a scientific standpoint it would be absurd to assert that the total pressure received by the top of the brick is equal to that received by the bottom, and that each is equal to that at the centre of the brick. In practice, however, one notices no difference, and the brick is, to all intents and purposes, uniform in density from top to bottom.

"The later toggle machines recognize the probability of this difference in the top and bottom and provide for it by an arrangement which, in a measure, reverses the motion at any point in the stroke. The claim has been made that the motion of the brick under pressure in the mould does not remove the granulated centres but simply glosses them over, and this claim is reasonable, since the centres are only removed through friction against the sides of the mould. In practice it is difficult to recognize any difference in density throughout the brick, but from a theoretical standpoint it is difficult to believe that the effect of the friction against the sides of the mould will extend to the centre of the brick with a material so irresponsive to pressure as dry clay. It is most probable that the internal core of the brick will have less density than the faces.

"If these differences exist they are too slight to be noticed in practice, but they may account for some trouble in drying and burning such a body as semi-dry clay, in which the bonding element is not developed as in the plastic process."

Scum is particularly troublesome in some clays used in the semi-dry process, and the use of barium carbonate is impracticable owing to the small amount of water used. Some advantage may be gained by using barium chloride, but great care is necessary to avoid an excess of this material, or the remedy may prove worse than the disease.

Drying Troubles.—Although, by sending bricks made by the semi-dry process direct to the kiln, the drying process with all its troubles is apparently eliminated, it is found in practice that "semi-dry" bricks need as careful drying as any others, the only difference being that it is carried out in the kiln instead of in separate dryers. The reason is that in "plastic" bricks the plasticity of the clay is fully developed and the granular particles are cemented together, but in the semi-dry clay the bond is largely mechanical. The colloid properties are

not developed, and, if the particles are connected at all, it must be with dust, and at best imperfectly. When the pressure is applied the particles are forced together and into each other, and held there by interlocking, assisted, of course, by whatever colloid properties may have been developed. The dust fills the interstices under various degrees of pressure according to its amount, and the protection it has received in the interlocking of the particles and the opportunity for the escape of the air during the final pressure. The air, in its escape, may play the further rôle of sweeping clean the points of contact of the interlocking particles.

Bricks held together by such a doubtful primary bond must be very carefully dried in the kiln from three to twelve days, and in some cases (as with large blocks) two and three weeks are required. It is more a sweating process than a drying one, so slowly is the moisture taken off. Rapid drying would loosen the particles, which would not reunite in burning, and the result would be a rotten brick.

It is seldom practical to vitrify dry-pressed bricks, as the finer state of division of the material in bricks made by the plastic process is sufficient to explain the more ready fusibility of the matrix, but in the dry process the contact of the particles alone forms the bond. The shrinkage is comparatively little, and is not due in any marked degree to the fine material.

As Ellis Lovejoy states: "In the one case the matrix fuses and contracts, carrying with it at all stages the larger particles, and imperviousness is attained with its fusion. In the other, the fine material may fuse and collect in the bottom of the cells formed by the larger particles, running into and around the points of contact, cementing them together into a permanent bond but only partially filling the cells, and imperviousness can only be effected by the softening of the cell-walls themselves, and the closing in upon the fused fine material contained therein."

An impervious brick made by the plastic process has a stony structure, while an impervious dry-press brick tends towards a glassy one.

Moulds and Arrises.—Semi-dry clay has a strong grinding action on the moulds or dies, and these must be kept in good order or the bricks will have bad edges. With badly worn dies there would be no pressure around the edges and at the corners, and without pressure there would be no primary bond, and the edges and corners would crumble off in handling, either before or after burning.

CHAPTER VII.

THE DRY OR DUST PROCESS.

NOTWITHSTANDING the many complaints which have been published by clayworkers who have been unsuccessful in producing a really sound brick in the "dry" way, this method is in great favour in different parts of the world, especially on the Continent, where the presence of enormous deposits of secondary clays, which are very difficult to work by more plastic methods, makes the problems confronting the clayworker more acute than they are here.

It must be obvious to all practical clayworkers that a highly plastic clay is not suited for working in a dry state, and that attempts to treat it in this way will most probably end in failure, though a few cases are known where satisfactory goods are being produced by mixing such clays with a large proportion of non-plastic material of somewhat coarse grain. As a general rule, therefore, the clays which are suitable for dry treatment are those of the secondary and shale classes, but other substances which are not of a truly argillaceous nature, such as steatite, lime-sand, or even concrete, may be treated satisfactorily in this way. The great essential appears to be that the material to be pressed shall have sufficient binding power, and yet shall be free from the stickiness inevitably associated with plastic materials in which the plasticity has not been fully developed.

The composition of the materials used will be found to be of minor importance as far as the actual production is concerned, though it must be considered in a study of the uses of finished goods. It is the physical, rather than the chemical, composition and nature of the clay which determines whether it can be satisfactorily worked in the dry way, or whether an admixture of water previous to pressing is necessary.

There are two reasons why the dry process of brickmaking appeals to brickmakers: First, the lessened cost of making, owing to the absence of all drying either in the kilns or in special yards

or sheds, and, second, the reduction in the number of cracked and split bricks as compared with the products of many yards working a plastic or stiff-plastic method.

Very coarse materials do not lend themselves readily to this method of manufacture, as a certain proportion of fine dust must be present to give solidity and strength.

An important point in the manufacture of dry-pressed goods is to have the material really dry, as otherwise its water content is apt to be unevenly distributed and a mixture is used which will crack in the kiln. On this account it is often necessary to dry the material before or after grinding.

Lamination requires far more attention than has hitherto been given to it if this really serious defect is to be removed. It is due in many cases to defective design in the presses, and to the inclusion of air between the particles. Almost all dry-presses at present in use cause a certain amount of lamination, though it is often too insignificant in extent to warrant any special comment. Its cause is obscure, but apparently the absence of lubrication, such as is supplied by the water in plastic clay, tends to permit the dry particles to move to different extents in different directions, instead of regularly, as in the more mobile, plastic clay. Lamination is especially marked in slightly moistened clays, in which some of the particles are dryer than others (see p. 237).

Dry-pressed bricks with sharp arrises, and which are perfectly sound, are difficult to produce when the moulds are worn, and as they leave the mould less rapidly and wear it more quickly than a well-oiled plastic brick, this is a matter of some importance, and one which must be fully considered when proposing to lay down a new plant.

Some dry-pressed bricks on the market are defective through being under-fired. As the binding influence of plastic clay is absent from such bricks, a somewhat higher temperature is often necessary in the kilns in order to bring about incipient vitrification, and so obtain a strong article. This effect of plasticity on the fired goods is by no means well understood, though it is undoubted. Probably it is due to the effect of the greater proportion of water in the plastic clay in splitting up the latter into finer particles, which commence to vitrify at a lower temperature than when they are in the coarser form of stiff bricks.

The methods and machinery used are precisely similar to those employed in the semi-dry process, except that no water is

added to the material, and some form of clay dryer may be required. Greater pressures are, however, necessary and the presses must be made exceptionally strong. The "Emperor" press (p. 234) is particularly suitable for materials practically devoid of plasticity.

The dry or "dust" process is chiefly used in this country for tiles, the manufacture of bricks by it being difficult on account of lamination, irregularity in hardness in different portions of the brick, and defective binding power before burning, which makes the bricks difficult to handle. With tiles the difficulties are much less because of their thinness. The small amount of moisture present in the bricks made by the semi-dry process overcomes these difficulties to a limited extent, and it is on this account generally preferable.

The advantages of the dry process over the others are many and obvious, but the process is limited to certain types of clay and classes of goods, and those clayworkers who rashly imagine that any clay may be satisfactorily made into bricks or tiles by it may find their mistake out when it is too late. In such cases, as in many others, an absolutely impartial opinion, given by one thoroughly acquainted with the disadvantages and advantages of each method, and with the composition and character of the clay and the goods to be made from it, is the best thing to obtain before the plant is laid out. Such advice cannot, naturally, be had for nothing; but its cost is far less than that of experiments with expensive plant and machinery which prove abortive after a few months' trial.

Provided that the clay is in a suitable physical condition, its use in a dry press is accompanied by many advantages, but until more is known of the exact physical characteristics required, all work in this direction must be somewhat in the nature of an experiment.

CHAPTER VIII.

KILNS.

The selection of a kiln for burning bricks is a matter requiring great care and skill, particularly if it is to be used in works where the annual output is very large. In a small works the problem is less complicated, as the choice is usually limited to some form of single or intermittent kiln.

Brick kilns may be classified into two main groups: (*a*) single or intermittent kilns, consisting of a single chamber, and (*b*) semi-continuous and continuous kilns, consisting of a number of chambers connected in such a manner that the gases and products of combustion produced in one chamber may be utilized in heating others.

Kilns used for brick-burning may also be divided into three classes according to the direction in which the air, flue-gases, and products of combustion travel, viz. (1) up-draught; (2) down-draught; and (3) horizontal-draught kilns.

Up-Draught Kilns are the most costly in fuel, but are convenient in many small yards and can usually be constructed cheaply.

An up-draught kiln for brick-burning usually consists of two side walls placed parallel to each other and containing a number of fire holes. An arched roof may be fitted over these walls, or a flat roof may be formed by covering the bricks in the kiln with a layer of bricks laid flat and making this tight with ashes. One or more small chimneys may be built on the top of the kiln, or a flue may be built and connected to a single large chimney erected at a convenient distance from the kiln. The heated air enters through the fire-holes and rises to the top of the kiln, whence it passes to the chimney, the kiln deriving its name from the upward motion of this air or draught.

The chief failing of the up-draught kiln is its irregular heating, the consequent large proportion of under-burned and over-fired

bricks produced, and the large proportion of fuel (seldom less than 12 cwt. per 1000 bricks) it requires.

Its advantages are the low cost of erection, simplicity of setting and drawing, and the low cost of repairs.

Down-Draught Kilns are amongst the best single chamber kilns known. They should really be termed "up and down-draught," as the air entering the fire-boxes rises towards the top of the kiln and is then deflected downwards, distributing itself throughout the kiln and passing through an opening in the floor to the chimney, which should be about 40 ft. high and 4 ft. diameter.

This type of kiln is used throughout the country for high-class bricks of all kinds, and is valuable on account of the even heating which can be obtained. Though usually built as a single kiln, it has been found that the same principle can be applied to continuous kilns, with the result that the economy of the latter, combined with the excellent colour and even heating of the former, produce an almost ideal kiln.

Down-draught kilns may be either circular or rectangular in shape, the latter being best for bricks. They may be made sufficiently large to hold 250,000 bricks, but most British brickmakers find a chamber holding 30,000 to 40,000 most convenient for single-chamber kilns.

Horizontal-Draught Kilns are those in which the air entering through the fire-holes travels largely in a horizontal direction before entering the chimney. The best known kiln of this type is the "Newcastle".

They are used for fire-brick manufacture and in other cases where a high finishing temperature is required. They are not usually economical in fuel, but are, if properly designed, less wasteful than either up or down-draught kilns, though usually they are built too short in proportion to their width. They may be made of various sizes, but a capacity of 25,000 to 30,000 bricks is most convenient. If very high temperatures are required it may be necessary to add fuel through the holes specially constructed in the roof, but for most building bricks this is unnecessary.

If a horizontal-draught kiln is constructed of a number of chambers so connected together that the flue gases pass from one chamber to the others in a straight line a *semi-continuous kiln* is formed. If two semi-continuous kilns are placed side by side and connected at each end by other chambers, the

chimney being placed in the centre or to one side, a ring kiln or *continuous kiln* is obtained.

It must be remembered, however, that, whilst any continuous and semi-continuous kiln regarded as a whole is of the "horizontal-draught" type, each portion or chamber in such a kiln may be worked on the "down-draught" principle.

The Newcastle or single horizontal-draught kiln may, in fact, be regarded as the forerunner of the modern continuous kiln.

Continuous Kilns have the great advantage of using but little fuel (3 to 5 cwt., as compared with the 12 cwt., of up-draught kilns for each 1000 bricks). Many continuous kilns are, however, spoiled by the lack of provision for keeping the fuel away from the bricks, and many of these are in consequence spoiled in the firing. Where proper fire-boxes are provided for the combustion of the fuel, it is possible to obtain bricks equal in every respect to the best produced in any single kiln and at a far lower cost in fuel than is otherwise possible.

Brickmakers who have not studied the recent improvements in continuous kilns have an impression that they can only be used for common bricks. This is quite erroneous, as several firms are now regularly producing some of the best facing bricks in the country in continuous kilns.

Having described the main characteristics of the chief patterns of kilns briefly, typical kilns of each class may now be studied in greater detail.

Clamp Kilns are best considered in a class to themselves. They are seldom employed except for temporary purposes and for hand-made bricks, and a typical clamp has therefore been described on p. 61.

The Up-Draught or Scotch kiln is of a simple yet effective type and is typical of this class of kiln. It consists of four upright walls forming a rectangular chamber, the two end walls being sometimes replaced by temporary ones so as to facilitate the filling and emptying the kiln. These openings are 36 in. wide with a permanent wall at each side of the opening, but in practice it is better to make the opening sufficiently wide to admit a horse and cart, as the bricks can then be loaded direct from the kiln into the vehicle. When the filling of the kiln is complete, each of these openings is filled with a temporary brick wall covered with "daub" or clay paste. The openings may reach to the ground level or not, as is most convenient.

The floor is often sunk about 4 ft. below ground level, but this

has the disadvantage that a cart cannot be taken into the kiln.

Along each side of the kiln are fire-holes or openings about 16 in. wide and 2 ft. to 3 ft. high. These openings should be lined with fire-bricks (which can be renewed when necessary) so as to reduce their width to about 12 in. They may also with advantage be arched with fire-bricks.

The whole structure is usually about 26 ft. long by 16 ft. wide and 12 ft. to 15 ft. high externally, the side walls being 18 in. to 40 in. thick and the end walls (with "wickets") 36 in. thick, but dimensions vary so in different places that no definite sizes can be stated as being the standard.

The sides of the kiln may be the thickest at the bottom and may taper (externally) towards the top (fig. 168), as it is in the lower portion that the greatest strength is needed to resist the expansion action of the heat.

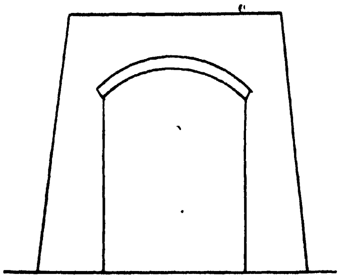


FIG. 168.—End of up-draught kiln (with extra large wicket).

Small chimneys may be provided on the top, if necessary, but it is usually found that they are not required. The top of the kiln may be closed with ashes, or a permanent arched roof may be employed.

Such a kiln is built of bricks set in clay paste. No ordinary mortar must be employed, except, possibly, for pointing the outside of the kiln, as the lime in it is detrimental to the hot brickwork when the kiln is in use. The walls must, usually, be supported by buttresses at the angles and, occasionally, at the sides.

An up-draught kiln of improved type designed by George Durant (fig. 169) burns 30,000 bricks at a time with an average consumption of 8 cwt. of fuel per 1000 bricks.

The fire-holes are 19 in. across, and are separated by 20 in. of brickwork and lined with $4\frac{1}{2}$ in. fire-brick linings. Doors and bars can be fitted to the fire-holes if desired, but these are by no means always necessary. Between each two fire-holes a smoke vent $4\frac{1}{2}$ in. wide is built, and a short chimney to each vent allows of the proper regulation of the draught in different parts of the kiln.

The foundation of the kiln should be perfectly water-tight, and in cases of doubt or dampness a layer of concrete 10 to 18 in. deep should be put down.

An important point in the construction of all kilns is the jointing of the brickwork, as if this is carelessly done the amount of loss through cold air leaking in and heat leaking out will be enormous. If the bricks are carefully dipped in "daub" and well malleted into position so as to secure a perfectly close joint, a considerable waste of fuel will be prevented. Lime mortar must not be used for jointing except at the outside facing, as it cannot stand the action of the heat inside the kiln. When carefully built and fired, no stays are necessary, though they can be used if desired. It is a great advantage, both in enabling the

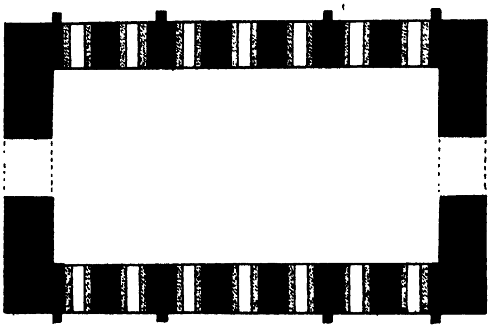


FIG. 169.—Plan of up-draught kiln.

fires to burn more steadily and in keeping the fuel dry, if a lean-to roof is erected along each side of the kiln. Many users of up-draught kilns omit this roof, though it is unwise for them to do so as it soon pays for its cost in the saving in fuel it effects.

The setting of the bricks in such a kiln requires considerable skill, as the courses must be crossed in such a manner as to leave continuous openings throughout, in order that the heat may be properly distributed. On this account flues about 8 in. wide and 2 ft. to 3 ft. high are left in the lower parts of the kiln connecting the fire holes in the side walls. One of the most satisfactory methods of setting such a kiln is to arrange the bricks in three straight lines, the centre one skintled, running from side to side, and to fill the kiln completely up to the top.

A circular up-draught kiln is only used to a limited extent (being preferably replaced by a down-draught kiln); there is no

need to describe it in further detail. According to E. Dobson, up-draught kilns of this pattern were largely used at one time for the burning of Staffordshire blue bricks, consuming about 4 tons of coal for a kiln capacity of 8000 bricks

The Down-Draught kiln, whether circular or rectangular, is the most efficient and satisfactory of all single kilns, yielding the most perfect colour and the lowest fuel consumption of any intermittent kiln.

For many years the most popular form of single down-draught kilns has been circular in shape, but for ordinary bricks the rectangular pattern has several obvious advantages and is relatively cheaper to construct.

Figs. 170 and 171 show a section and plan of a circular down-

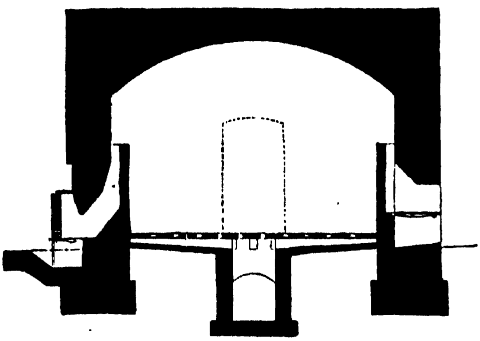


FIG. 170.—Section of down-draught kiln.

draught kiln. For bricks, such a kiln has usually ten or twelve fire-holes around its circumference, and the hot gases from these rise up through a series of pockets or "bags" towards the top of the kiln, whence they are turned downwards, distributing themselves through the bricks in the kiln and finally passing through the central flue to the chimney. In most down-draught kilns of this pattern the floor is solid with the exception of the central flue, but in some cases a perforated false bottom is added so that the gases may be better distributed amongst the goods in the kiln. The chimney is usually external to the kiln, but may be placed centrally inside it if desired. Instead of the bags or pockets through which the fire-gases rise being separated from each other, it is, in some cases, preferable to use a continuous flash-wall or screen running completely round the inside of the

kiln, so as to spread the gases more than is the case when bags are used.

In any case, the bag, or screen-wall, must be perforated near to the bottom so that some of the gases may penetrate at once to the lower part of the kiln. If this is not done, and the walls are solid throughout, the lower portion of the kiln will probably be under-fired.

It is usual to connect several kilns to a single chimney, but, if this is not practicable, each kiln may have its own shaft. Occasionally, round kilns are connected to each other so as to form semi-continuous kilns, but such an arrangement is seldom quite satisfactory.

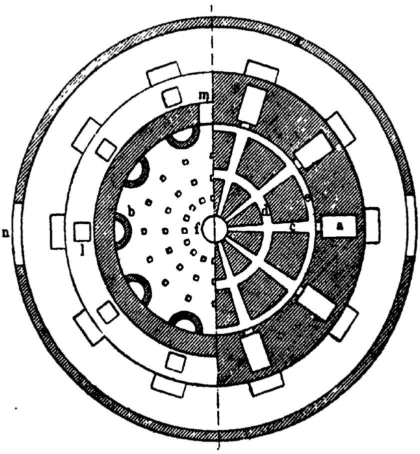


Fig. 171.—Plan of round down-draught kiln.

The walls of a circular down-draught kiln must be of considerable thickness, and must, usually, be surrounded by iron bands in order to prevent it being damaged by expansion.

The fire-boxes may be simple openings in the walls of the kilns fitted with a grate about 14 in. wide, or they may, preferably, be in the form of a box or hopper as described in connexion with a rectangular down-draught kiln. The box form has the advantage of giving more regular heating with less fuel, as it prevents much leakage of air through the fire-holes. The grates may be flat or sloping, the latter being preferable, as they expose a larger area of fuel and prevent air-leakage when the fuel is partly burned.

In the ordinary fire-box the most elementary requirements for the efficient burning of the coal are to a large extent omitted, with the result that much fuel is wasted and a large amount of smoke produced.

Most kiln builders appear to forget that when fresh fuel is fed on to a fire the amount of air needed whilst gas is being produced is very large and that this air must, for the most part, be introduced into the gas stream direct and must be shut off when the production of gas has ceased. For this purpose an air-flue which can be closed by a door or by bricks should be constructed some inches above the furnace and should lead directly into the kiln bag or screen-space. The fire-box must be of such a shape that the coal will lie on the grate and will form its own seal, preventing much heat escaping outside the kiln. To secure this it is necessary to have the grate much more sloping than is usual, so as to allow the fuel to lie at an angle inside the furnace.

A similar principle is employed in the Gillet fire-box, but in this case several parallel air openings are provided. A large iron hopper is also placed on top of the square masonry.

The use of a grate is not necessary with some fuels, but it is generally an advantage.

If the fire-boxes are made sufficiently deep (above 30 in.) a species of gas-producer is formed which is very effective and economical. When using smudgy coal the difficulty sometimes experienced with so deep a fire-box can be overcome by blowing steam and air into the fuel near the bottom. This is best accomplished by fitting a 2-in. iron or stoneware pipe into the front of each fire-box, and allowing it to project about half-way inside the latter. A steam jet $\frac{1}{8}$ in. diameter is then attached just inside the outer end of this tube, so that the steam passing through the tube carries a supply of air with it. As the steam must usually be brought a considerable distance, much condensation occurs, so that some form of superheater is necessary. This is easily obtained by fixing a U-shaped iron pipe 2 in. diameter just above the gas exit of the fire-box, and connecting the ends of this pipe to the boiler and steam jet respectively. If the action of the heat on the iron U tube is excessive, a thin fire-clay slab may be placed beneath it. A larger steam jet than that mentioned is undesirable, and the superheater must not be omitted if the best results are to be obtained.

In order to overcome the difficulty experienced in drying and

warming the lower bricks in a down-draught kiln, and in preventing the deposition on them of condensation-products from the upper bricks, E. Thomas has patented the use of a number of supplementary fires placed between the ordinary fire-boxes and connected to a different pattern of "bag" (fig. 172). These supplementary fires are used entirely for the heating of the lower part of the kiln before, or simultaneously with, the heating in the usual manner. For this purpose the "bags" are nearly closed at the top as shown in fig. 173, but are open at the front, so that the fire-gases are confined to the lower 3 ft. or so of the kiln. By heating this portion first (instead of last as in the ordinary

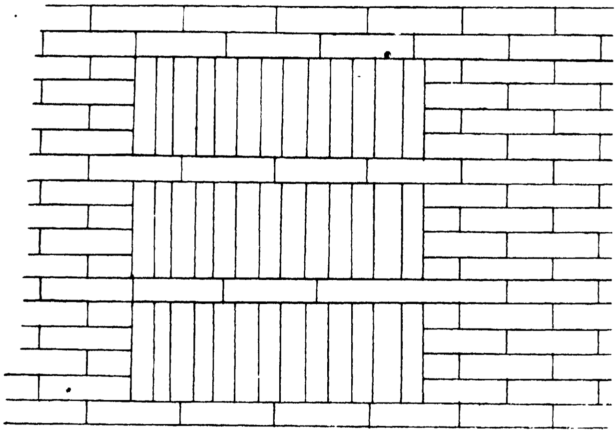


FIG. 172.—Special screen (front view).

manner) the bricks contained in it are made better able to stand the pressure of those above them. They are warmed and so cannot be spoilt by condensation deposits, the draught of the kiln is improved and the amount of fuel required is slightly reduced. These supplementary fires are fitted with doors so that the heat from them may be regulated, and it is found in practice that they enable the bottom of the kiln to be finished as soon as the top.

The rectangular down-draught kiln shown in figs. 174 and 175 is easier to set than a circular one. It may have a single separate chimney, or two smaller chimneys, one at each end, or a series of very small chimneys, one for each fire. The first mentioned is the best, though it may be more expensive if only

one kiln is built, the only advantage claimed for the use of a separate small chimney to each fire being that a separate control of the draught is obtained. This may be equally well arranged, when desired, by inserting dampers in the separate flues leading to the main.

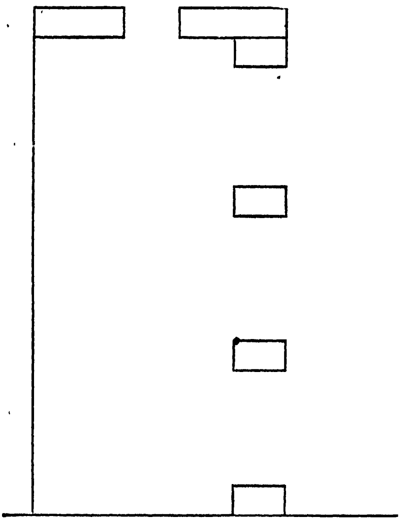


FIG. 173.—Cross section through centre of fig. 172.

The walls should not be less than 30 in. thick and should be strengthened by vertical steel joists placed at intervals on each side of the kiln, and tied together by 1-in. rods to those on the opposite side of the kiln. In order to strengthen the kiln at the springing line of

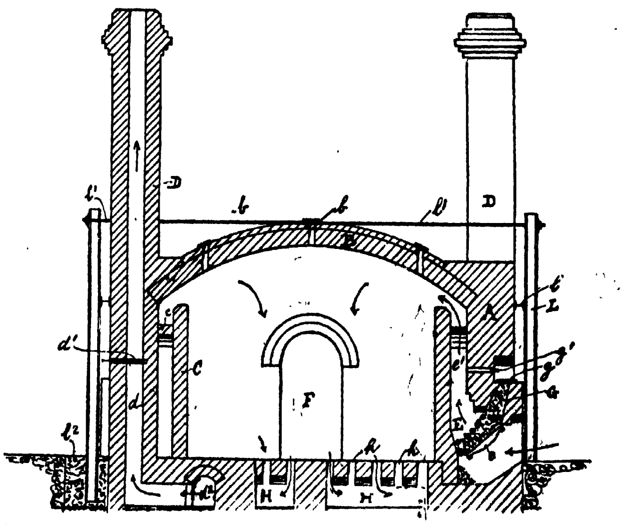


FIG. 174.—Cross section of down-draught kiln (on line *zz*, fig. 175.) (Brown).

the arch, horizontal steel joists should be placed around the kiln at this level and kept in place by the vertical ones.

The kiln has an arched roof. The fuel is burned on inclined grates fixed in fire-boxes down two sides of the kiln. These fire-boxes are so made that a considerable quantity of fuel is contained in them, the gases and volatile matter from the fuel being drawn downwards and passing over the glowing fuel in a manner impossible with a flat grate. This not only saves fuel but reduces the amount of smoke. The inclination of the grates must be adjusted to suit the fuel used, and experiments may be necessary

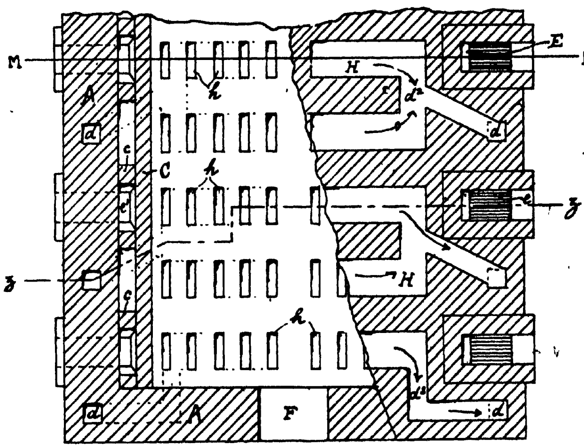


FIG. 175.—Half-plan of down-draught kiln (Brown).

before the correct angle can be found, though it is usually about 60 degrees. The grate-bars should not reach quite to the wall at the back, a space for pushing down the ashes being desirable. The air necessary for the combustion of the fuel enters chiefly through the grate, but an additional supply can be admitted through an opening in the wall above the fire-box. The admission of this additional supply of air is of great importance in aiding the prevention of smoke, and by constructing a series of vertical flues within the kiln-walls and parallel to the bag-walls a supply of hot air can readily be obtained. By this means the production of smoke is almost, if not entirely, prevented. This hot air is admitted to the bags at a point about 2 ft. above the level of the

fuel at the bottom of the bag, the amount of air entering the kiln being controlled by a simple damper.

The flame, fire-gases, and air rise through the bags and, after deflection from the roof, distribute themselves amongst the bricks. As it is essential that this distribution of heat should be even, the "bags" are sometimes replaced by a single wall or screen built parallel to the sides of the kiln forming a space or trough, into which the fire-gases are discharged. Cross- or tile-walls may be used between the fires to bind this wall to the kiln. As will be seen, the bags or screen-walls rise to the height of the spring of the arch or even higher, but ample room must be left in the top of the kiln for the effective combustion of the gases. A few perforations should be left near the bottom of the bag- or screen-walls in order to supply some heat to the lower part of the kiln during the earlier stages of the firing. The supplementary fires described in connexion with the circular down-draught kiln may be used if desired.

The floor of this kiln is perforated so that the heat may be well distributed, each series of perforations leading to a separate flue. These flues are connected to a series of chimneys or to a main flue running beneath the kiln floor to the chimney-stack. If two chimneys are used (one at each end) the sub-floor flues should be connected to each chimney alternately, so that all the fires on one side of the kiln will lead to one chimney and those on the opposite side to the other.

There are no fire-holes at the ends of this kiln, their place being taken by "wickets" or "door-gaps," through which the kiln is filled and emptied.

The size of the kiln may be varied to suit special uses, but one capable of holding about 30,000 bricks, leaving ample space between them and the arch, will be found to be most generally useful. If built of ordinary bricks, with the exception of the bag-walls and the lining of the fire-boxes—which should be of fire-bricks, a kiln of this size will cost about £250, but if any independent chimney-shaft is used the cost of this must be added.

The bricks may be set "five on two," i.e. five headers on two stretchers, or in "blades" as preferred. In each case, care must be taken to allow the gases in the kiln to have access to the perforations in the floor, and the first two or three courses of bricks must be arranged accordingly. The bricks should not be set much above the level of the bag-walls, and in no case within

15 in. of the top of the kiln, as this space is necessary for combustion and heat circulation.

Down-draught kilns should be built rather low—16 ft. high inside is too high for most purposes, and 10 ft. would be far better.

The *Newcastle* kiln (fig. 176) is typical of horizontal-draught kilns. Unlike the up-draught kiln previously described, it is fired from the end instead of from the sides, with a consequent saving in fuel. In most Newcastle kilns this firing is from one end only, the chimney being placed at the other, but in kilns of 20 to 30 ft. or more it is usually necessary to fire from both ends.

It is customary in some districts, though not in Newcastle, to fire through holes in the roof of kilns of this type, the fuel being received and burned in special "pillars" constructed of

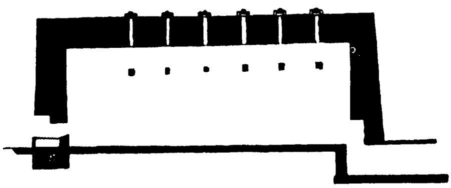


FIG. 176.—Longitudinal section of "Newcastle" kiln.

the bricks to be fired. As this arrangement spoils a certain proportion of bricks it is not to be recommended except in the case of common goods.

The Newcastle kiln consists of a long rectangular chamber with an arched roof. It is not usually more than 15 ft. wide internally and is often much narrower. One end of the kiln is solid and has a chimney, or three flues leading to a chimney, at the back of it; the other has two permanent fireplaces and a wicket or door gap about 40 in. wide, in which, when the kiln is filled, a third fireplace is constructed.

These fireplaces, as ordinarily built, each consist of an opening about 2 ft. 6 in. by 1 ft. 4 in. reaching from the ground, usually containing a grate, and another arched opening just above, and of the same width, but only 14 in. high at the centre of the arch, through which the fuel is fed. These openings should be partially closed by means of iron sheets or fire-clay slabs, though in practice they are left quite open in spite of the

waste of fuel which is thus involved. To obtain the best results they should only be sufficiently open to admit the proper quantity of air.

A space at least 3 ft. wide at the bottom and 4 ft. at the top should be left between the bricks to be burned and the inner face of the end wall of the kiln. This space forms a combustion chamber, and when no grates are used for the fuel it forms an ashpit and bed for the combustible. It is necessary to have this space in order that the air- and fire-gases may be properly commingled and the fuel thus be perfectly burned.

These gases travel along, chiefly in a horizontal direction, but distribute themselves through the bricks, finally passing out through three openings at the farther end of the kiln, to the chimney. If the kiln is longer than 30 ft. it is desirable to have exit openings in the side walls and floor of the kiln at intervals, so that the gases may be taken out as required. This is especially necessary during the earlier stages of firing, as if the gases become too cool they will cause deposits (scum) to form on the goods. Very large Newcastle kilns are, however, undesirable, as smaller ones connected together to form a semi-continuous or continuous kiln have many advantages and are equally economical in fuel.

For convenience, and to reduce the cost of building, Newcastle kilns are often erected in batteries of six kilns placed side by side. When this is the case it will be found much more economical and satisfactory to erect a semi-continuous kiln of the same capacity.

The setting of the bricks is similar to that in a continuous kiln.

Gas-Fired Single Kilns have been made the subject of many patents, but few have proved really successful. Most patentees have had an insufficient knowledge of the firing of kilns, and have attempted the impossible by introducing the gas at the wrong place, or have tried to keep it alight when supplied with cold air.

For the successful application of gas to intermittent kilns it is necessary to have several kilns so placed that they discharge their waste gases into one of two central regenerators or chambers filled with bricks arranged in a chequer-work fashion. Whilst the waste gases from a kiln are passing through one of these regenerators the brickwork becomes heated, and when the supply of gases is cut off by being diverted into the other regenerator, air is drawn in the opposite direction through the first

one; thus the air becomes heated and is then in a suitable condition for being supplied to the gas used for heating the kiln. The change of air and waste gas currents through the regenerators must be made at regular intervals of about thirty minutes, this being effected by means of a simple reversing valve.

The gas is made in special producers, the construction of which needs special skill. The gas-burners must also be of special construction; most of those who have endeavoured to apply gas to brick burning in single kilns have failed to burn the gas satisfactorily.

A typical arrangement for a single kiln fired by gas (fig. 177) is designed by E. Schmatolla, and found to be specially suitable

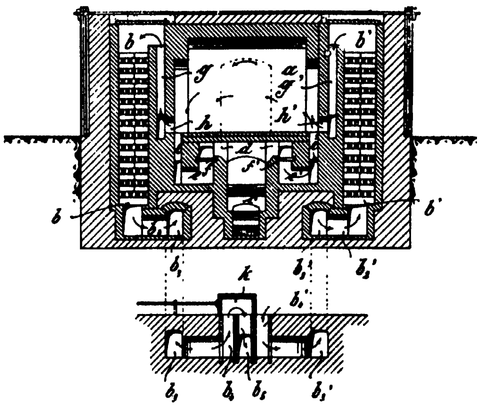


Fig. 177.—Intermittent gas-fired kiln.

for use at temperatures higher than can be obtained by direct firing with coal.

It consists chiefly in the connexion of the heating chamber with two or more heat collectors, accumulators or regenerators; the furnace proper is arranged so that it may be started as a direct fired grate, and afterwards changed gradually to gas firing, and on this account it is built centrally to the whole structure, the regenerators being placed at each side.

The gas generator (*c*), which is built in a similar way to a grate furnace, but with a higher shaft, is arranged below the burning chamber (*a*), and the two heat collectors or accumulators reach approximately from the bottom end of the gas generator to the upper end of the heating or burning chamber. The gas generator is connected to the chamber at both sides by means

of conduits or flues (*d, e,*) between which are arranged dampers (*f*), the latter making it possible to close the one or the other of the flues (*d*). The two heat collectors (*b*) are connected to the heating or burning chamber (*a*) by means of conduits (*g*) and openings (*h*). The heat collectors, which are provided with a grating of refractory bricks or other material, are connected at the bottom end to conduits (*b*1, *b*2, *b*3, *b*4), which can be brought into communication either with the chimney channel (*b*5) or with the outer air by means of a device consisting of a box (*k*). Assuming that the damper (*f*) on the left-hand side is closed, the corresponding damper (*f*) on the right-hand side being open, and the box standing as shown in the drawings; the conduit (*b*4) on the right-hand side is in connexion with the outer air, and the conduit (*b*4) on the left-hand side is connected with the chimney; and assuming further that the generator is filled with coal, and that the whole furnace is already incandescent, the generator gas will then pass through the right-hand conduit system (*d, e*) into the heating chamber (*a*), and the air through the right-hand conduit system (*b*4, *b*3, *b*2, *b*1), the grating of the right-hand collector and the conduits (*g, h*) also into the heating chamber (*a*). Gas and air become mixed at the right-hand end of the chamber, burn in the interior of the chamber (*a*), and pass at the other end through the conduits (*h, g*) and the heat collectors (*b*), as well as the conduits (*b*1, *b*2, *b*3, *b*4) on the left hand, into the chimney. The combustion gases escaping from the chamber give off the greatest portion of their heat to the grating of the heat collector arranged on the left-hand side. When the latter is so highly heated that the combustion gases begin to escape through the flues (*b*1, *b*2, *b*3, *b*4) at a higher temperature, the box (*k*) is drawn to the right side, so that the left channel (*b*4) is open and the right channels (*b*1, *b*2, *b*3, *b*4) are connected to the chimney. If, then, the right-hand damper (*f*) is closed and the left-hand one is opened, the gas will pass through the left-hand side flues (*e*) and (*g*) into the chamber, and the air will pass through the left-hand side flues (*b*4, *b*3, *b*2, *b*1), the grating of the left-hand side heat collector, and the right-hand side flues (*g, h*) into the chamber. The direction of the flame will be reversed, and it will pass on the other side through the flues (*g, h*) to the heat collector, and after having given off to the latter the greatest portion of its heat through the right-hand flues (*b*1, *b*2, *b*3), into the chimney. The air is, of course, highly heated by the previously highly heated left-side accumulator,

and passes into the chamber with a very high temperature. The producer gas will also pass into the heating chamber at a very high temperature, since it has to traverse only a short conduit, and thus it is possible to increase the temperature in the chamber to a much higher degree than is possible in the furnaces generally used—for instance, for burning or heating highly refractory materials. As the direction of the flames can be altered at given intervals of time, the temperature in the chamber can be raised as much as desired up to the limit of the dissociation temperature of carbonic oxide—that is to say, up to 2000° C.

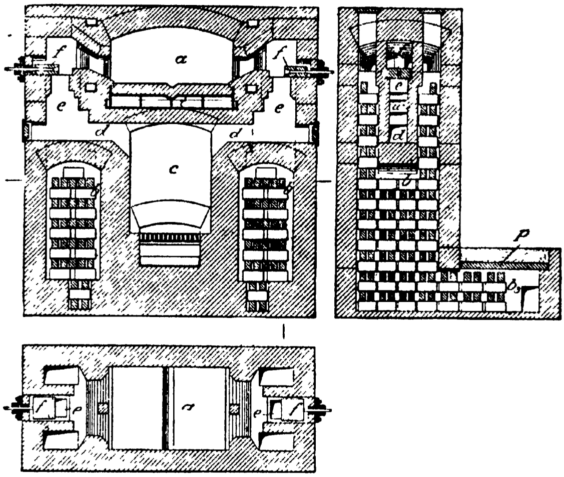


Fig. 178.—Regenerator and furnace.

An adaptation of this regenerator to a furnace is shown in fig. 178. In this, the heat accumulators (*b*) are placed at the side of the producer (*c*) as before, but the gas flues (*d*, *e*) are arranged at each side in the middle of the accumulators (*b*), separated from them by thin walls (*w*), whereby the accumulators are divided at the top into two branches, which are also filled with brickwork for accumulating heat and communicating at their upper end with the combustion chambers (*a*). In this arrangement the dampers (*f*) for regulating and reversing the gas and air are arranged at the level of the heating chamber inlets, and are controlled from the sides of the furnace instead of from the front. By means of this arrangement it is possible to look through the

flues direct into the gas producer, and consequently the cleaning of the gas flues is quite easy. In this way it is possible to cool the bottom of the hearth from a water tank (t), a great advantage when the furnace is used for melting purposes, or where a fusible slag is produced. This drawing also shows a design when the flues (b^3) leading to a separate reversing box (k), as in fig. 177, are used as a part of the accumulator by filling them also with brick-work; in this they can be covered with plates (p). By this system the whole of the heat in the waste gases may be recovered, and experience has shown that, whilst the heating chamber is at a white heat (1700° C.), it is easy to keep one's hand on the reversing valve (k), (fig. 177).

The Mond Gas Producer has also been applied to the firing of kilns, but as the essential feature of this plant is the recovery of by-products from the fuel, it can only be used where a very large number of kilns are employed at a time. In such cases it is easier and better to use a continuous kiln—either coal or gas-fired—for burning bricks.

A system of what may be termed "half-gas" firing has been successfully applied to kilns by A. Woolley and others. This consists in removing the grates from the ordinary fire-boxes of the kilns, providing an air-tight door, and blowing in air and superheated steam below the fuel. A crude gas is produced without any appreciable alteration of the furnaces, and regular heating is greatly facilitated with a reduction in the amount of fuel consumed, and a great saving in the labour of firing and of cleaning out the fire-boxes.

Semi-Continuous Kilns are those in which the unused heat from one chamber is used in others, the transference being continued until the end of the series is reached. Semi-continuous kilns are, therefore, more economical in fuel consumption than are single kilns, and yet, if rightly constructed, they give equally good results. Unfortunately, most designers of semi-continuous kilns have been unduly influenced by their knowledge of the Newcastle (single) kiln and the Hoffmann (continuous) kilns, and have overlooked the advantages of the down-draught kiln when connected to form a semi-continuous series. On this account many semi-continuous kilns do not produce bricks of good colour, but the fault lies less with the underlying principle of semi-continuous action than with its limited applications.

The general structure of a semi-continuous kiln is shown in fig. 179, though the use of only four chambers would not secure

a great reduction in the amount of fuel used, and at least six chambers should be connected. The kiln shown is practically a Newcastle kiln with fires at one end, to which have been added three other chambers for which no fire-grates have been provided, though feed-holes for the fuel are placed in the roof.

Chambers 1 and 2 having been filled with bricks the fires are lighted and the heat not required in No. 1 is taken through the five short connecting flues direct to chamber 2. Passing through this, it escapes to the chimney through underground flues situated at each side of the kiln. As soon as the succeeding chambers (3 and 4) are filled, the gases are passed through them before being admitted to the flue, and, in this way, almost the whole of the heat in the gases is used. As soon as the bricks in chamber 1 are finished, the firing in the fireplaces is stopped, and the fuel supplied as required through the roofs of the different chambers.

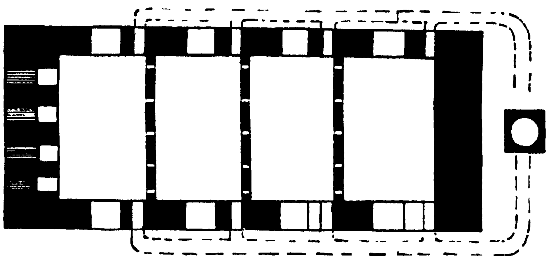


FIG. 179.—Plan of semi-continuous kiln.

It will easily be seen that whilst the heat from No. 3 chamber is fully used in heating bricks in other parts of the kiln, much of the heat from No. 3 and all from No. 4 must pass into the chimney and be lost, so that the saving in fuel depends very largely on the number of chambers (i.e. on the length) of the semi-continuous kiln.

If such a kiln be constructed with fourteen or more chambers, and these, instead of being in a straight line, are in the form of a circle or ellipse, the fireplace necessary in the semi-continuous kiln is no longer needed, and a continuous kiln, in which the waste above mentioned does not occur, is produced.

Another serious objection to the semi-continuous kiln just described (where the colour of the goods is of importance) is the damage done to some of the bricks by feeding the fuel amongst them through openings in the roof. This may be overcome by the use of grates or fireplaces in each chamber, whereby the fuel

is prevented from coming into contact with the goods, and bricks of an excellent colour may then be produced.

Occasionally, two semi-continuous kilns are built side by side, one being burned whilst the other is drawn or set. This simplifies

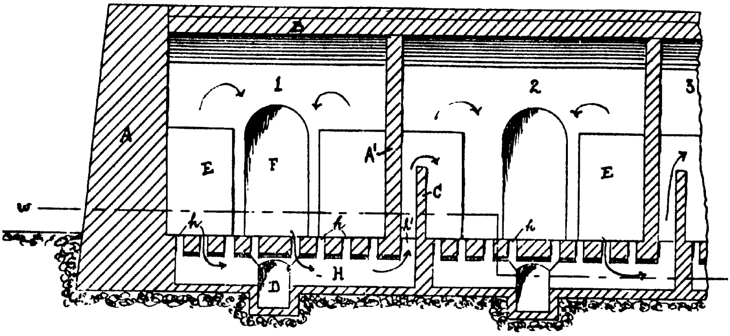


FIG. 180.—Section of semi-continuous kiln.

the construction somewhat, but is awkward in use compared with the semi-continuous down-draught kiln with one gallery shown in fig. 180, and is not so economical as a continuous one.

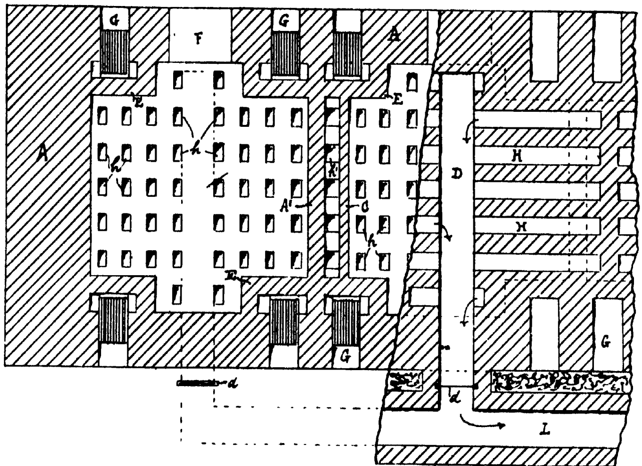


FIG. 181.—Part-plan of semi-continuous kiln.

The Semi-Continuous Down-Draught Kiln shown in figs. 180 and 181 is due to A. E. Brown, but similar principles are used by other designers of kilns of this style, and many of the better con-

tinuous kilns can be made into excellent semi-continuous ones by building a few chambers instead of the whole kiln.

Each chamber in such a kiln can be used independently of the rest—an important advantage when the supply of green bricks is short or when the output of the works is reduced.

As shown in fig. 180 a number of chambers (usually six) are connected with each other by means of a row of openings in the floor next to the partition walls, so that the fire-gases pass through these openings to the next chamber. The furnaces, in this case, are arranged in each corner of each chamber, and direct communication with the chimney can be made through a damper-controlled flue in each chamber. The chambers may conveniently hold 7,000 to 15,000 bricks each, and if only six are erected the whole set should be filled, burned off, and cooled before being drawn and reset, though with careful working it is possible to set some chambers at the same time as the others are being fired.

When starting the firing the damper (*d*) and the flue (D) is opened and the fire-gases pass through the perforations to the chimney through the main flue (L). By keeping this damper open, any chamber can be worked independently, but on closing it the fire-gases pass into the next chamber through the perforations and under the partition walls, rising through the openings in the next chamber up what is practically a "bag". The chimney damper of this second chamber may be opened, or if closed that of a later chamber must be opened. When the firing of a chamber is finished, the fires are allowed to die out, the openings for admitting fuel are closed, and the finished chamber only used for the supply of such hot air as may be needed. Such a kiln with a suitable chimney would cost about £500 for a chamber capacity of 7,500 bricks and a weekly output of 15,000, but the saving of fuel on this output would repay the extra cost of the kiln over single ones within five years.

Continuous Kilns have increased steadily in popularity during recent years, and though still misunderstood and mismanaged by many brickmakers, the prejudice which existed against them at one time is slowly dying out.

In this country few brickmakers would attempt to use a continuous kiln for an output of less than 1,000,000 bricks yearly, though in Germany many small kilns of this type are in use.

For an annual output of 1,000,000 or more bricks some form of continuous kiln is very desirable, the precise construction

depending upon the class of bricks to be produced. The first successful continuous kiln was invented by Frederick Hoffmann in 1859, and though many improvements have been made since that day, the general principle he employed is still used, and many modern kilns are termed "Hoffmann," although they differ widely from the original one of that name.

For common bricks the original type of Hoffmann kiln is quite satisfactory, but as it seldom yields as much as two-thirds of its contents of facing bricks the proportion of those of second and third quality is very large. This type of kiln is characterized by a remarkably low fuel consumption—averaging $3\frac{1}{2}$ cwt. per 1000 bricks as compared with 10 to 12 cwt. for single kilns—but the first cost is necessarily great, though not so high in proportion as many brickmakers are apt to suppose.

Although many patent continuous kilns are on the market, it will be sufficient if seven main features are described and compared, the characteristics of certain other well-known kilns being mentioned according to the class in which they occur. The chief features of modern continuous kilns are:—

1. The general principle of continuous action, typified in the simple Hoffmann kiln. In this the fuel is fed through the roof and burned amongst the bricks to be fired.
2. The use of grates or troughs for the fuel.
3. The use of flues for supplying the freshly-set bricks with warm air, in order to dry them and to prevent the deposition of moisture on them—as in most modern continuous kilns.
4. The use of the down-draught principle—usually in connexion with grates or troughs for the fuel (see 2)—and permanent partitions so as to divide the kiln into a number of separate chambers.
5. The means used for removal of steam.
6. The use of gas in place of solid fuel.
7. The use of mechanical (fan) or natural (chimney) draught.

The simple Hoffmann kiln was originally circular in shape, but it is now frequently made with two straight portions connected together by two semicircular ones so as to form an ellipse with flattened sides. This later pattern is more convenient in shape than the circular one. The general construction and method of working of this, the simplest and oldest type of continuous kiln, is shown in figs. 182 and 183, from which it will be seen to consist of a circular tunnel with twelve door-gaps in its outer circumference and twelve flues in its inner one. The

door-gaps give access to the interior of the kiln and are closed with brickwork when those portions of the kiln in which they occur are being fired; the flues lead to a central annular flue connected directly to the chimney, the connexion between the twelve flues and the annular one being controlled by dampers.

The outer walls of the kiln must be at least 3 ft. thick, and must be set in buttress form so as to resist the great effect of the heat upon them. The masonry in the centre of the kiln is composed of brickwork filled in with rubble or broken bricks, well stamped down so as to yield a solid mass. The fuel is supplied through holes in the roof of the tunnel.

The size of the kiln may be varied to suit different conditions, but it should have at least 14 "chambers" each at least 12 ft.

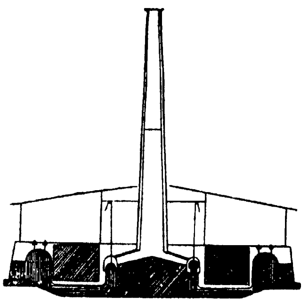


FIG. 182.—Vertical section of Hoffmann kiln.

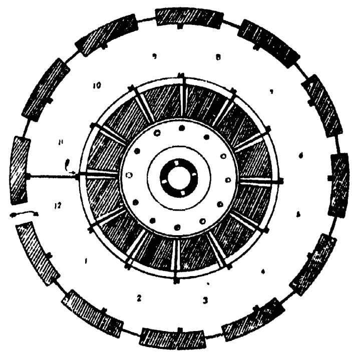


FIG. 183.—Plan of Hoffmann kiln.

in length or an average tunnel length of 168 ft. It is found that better results are obtained with an average tunnel length of about 225 ft., and this the author considers a desirable minimum for the manufacture of first-class bricks. The earlier kilns, with only twelve chambers, were too short for obtaining the best results, and in the best modern continuous kilns sixteen chambers are considered to be essential.

In considering a Hoffmann kiln it must be remembered that no partitions exist to separate the kiln into a definite number of chambers. The term "chamber" is, however, so convenient that its use in this connexion is universal.

The whole of the chambers, with the exception of two, having been filled with bricks which are being heated, the working of a simple Hoffmann kiln is as follows: "chamber" 1 is empty,

12 is being filled, and a current of air entering through the doorway of No. 12 through No. 1 on, gradually becoming hotter in its journey, thus helping to burn any fuel with which it may come into contact. No. 11 chamber is the one last filled, and consequently contains the coolest of the unfired bricks, the hottest bricks being in Nos. 4 or 5; the intermediate chambers being at varying but progressively increasing temperature.

The air passing *contra* clockwise round the kiln is, during its journey through the hottest chambers, highly charged with flue-gases, and the mixture so formed is purposely taken through as many chambers as possible so as to expend most of its heat in warming the goods. Finally, at a temperature of 150° C., and nearly saturated with moisture, it passes into the chimney and is lost. Meanwhile, the bricks in the various chambers are increasing in temperature as the result of the hot air and gases, and the fuel fed through the roof of the hotter chambers; and when those in (say) No. 4 are sufficiently heated, no further fuel is supplied to them. This chamber will then begin to cool, because of the current of air drawn through it as already described, and another chamber (say) No. 9, which has hitherto been heated by the hot gases alone, will be sufficiently hot to be fed with fuel through the roof.

In such a kiln, therefore, No. 1 chamber will be empty, Nos. 2 and 3 will be cooling, No. 4 will be at full fire and nearly finished, Nos. 5 to 8 will be under fire and hot, Nos. 9 to 11 will be being warmed by the "waste gases" from the previous chambers and No. 12 will be being filled. The partition shown between Nos. 11 and 12 will be placed between Nos. 12 and 1 as soon as No. 12 is filled, or as soon as possible after No. 4 is finished firing.

With some clays the gases become so charged with moisture that the foregoing procedure must be modified, and the freshly set goods warmed by special fires in the door-gaps or wickets. It is to avoid this that hot-air flues (see later) are used.

In the Hoffmann kiln as originally designed, the fuel, fed through the roof, falls into hollow pillars formed by the bricks to be burned on account of the special manner in which they are "set" in the kilns. The ash from this fuel discolours these bricks and renders them unsightly, but the saving in fuel effected by the kiln was for a long time considered to outweigh this disadvantage. In recent years, however, the demand for a better-coloured brick than can be produced by the original Hoffmann

kiln has increased so much that few modern brickmakers would now erect one of these simple kilns, but would include several improvements such as those described later. The fact still remains true, however, that the original Hoffmann is the most economical in fuel of any continuous kiln on the market, none of the "improved" kilns being able to work with less than 3 cwt. per 1000 bricks using a clay or shale free from any combustible matter.

In judging the fuel-consumption of a kiln it is necessary to ensure that there is no combustible matter in the clay as, otherwise, any comparison is useless. For example, the Fletton shale contains so much oil as to render only a trifling proportion of fuel necessary, and a kiln which will burn this satisfactorily with only ½ cwt. of coal per 1000 bricks may need 5 cwt. for a South Country clay or for a Midland marl.

Where the colour and appearance of the bricks are unimportant the simple original Hoffmann principle (fig. 182) is still the best.

Hoffmann Kilns with Grates or Troughs for the fuel, mark a distinct step forward in the production of facing bricks in a continuous kiln, as by keeping the fuel out of all contact with the goods they eliminate one of the chief causes of discoloration.

In the original "Belgian" kiln the grates are placed transversely—one in each chamber—the fuel being fed through holes in the roof or through a door at one end of the grate. With this exception the Belgian kiln is almost identical with the original Hoffmann one, though it is usually built of an oblong shape instead of being circular in form, and the chimney is at one side instead of being placed centrally. Like most modern continuous kilns the "Belgian" has a large number of chambers, frequently twenty-two.

In several other kilns this arrangement of grates is employed, and it has now become a recognized feature of continuous kilns for facing bricks. These grates may be of metal or of fire-clay, the former being generally preferable, being stronger.

In kilns designed by Guthrie and by Brown the grate is replaced by a trough or gutter in which the fuel is burned. The hearth patented by A. E. Brown is shown at *f* in fig. 184 and is sloping, the air being admitted to the side instead of below the fuel. This hearth is placed below the floor level and is found, in practice, to give results quite equal to the ordinary grate bars and to be somewhat easier to clean, as but little clinker adheres

to the air inlet. Flat grates are, however, quite satisfactory with proper care.

In the arrangement devised by Guthrie the trough has a level bottom, is somewhat deeper, and has no grate.

The openings through which fuel is fed to the fire-boxes must be capable of being closed to prevent the use of cold air, but a sufficient supply of air must be admitted to enable the fuel to burn properly and to prevent the grate bars (if of metal) from being melted. The means by which this air is admitted will be described later.

The advantages of grates, or troughs, running the whole width of each chamber are so numerous that they may be considered

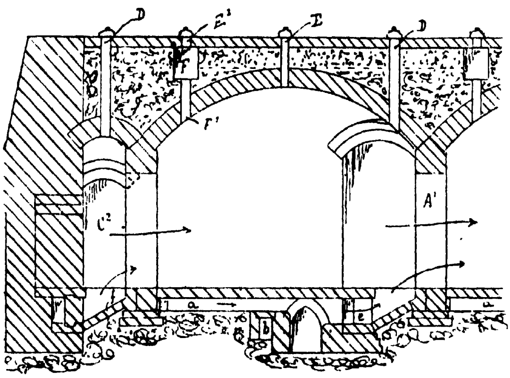


Fig. 184.—Section of one chamber in Brown's kiln.

an essential feature of all modern continuous kilns, and the question now facing brickmakers is not whether a grate or trough is necessary, but whether one is sufficient for each chamber. For most purposes a single grate or trough for each 15 ft. of tunnel is amply sufficient, but where unusually high temperatures—as in fire-brick and blue-brick manufacture—are required, it is desirable to employ two grates or troughs to each chamber. This arrangement has been patented by Barnett & Hadlington.

Hot Air Flues are essential in the production of well coloured bricks in continuous kilns, and the chief variations in modern kilns of this type are due to the different means used to supply heated air.

Hot air is used for two purposes in the best continuous kilns, viz.: (1) for facilitating the combustion of the fuel on the grate

or in troughs or bags, as a better result is obtained when the fuel is supplied with hot instead of with cold air; and (2) for drying and warming newly set goods. In some of the older types of continuous kilns hot air is exclusively used for the former purpose.

It has already been stated that if the fire-gases be taken through too many chambers in succession they will become cool, and being heavily charged with moisture and other combustible impurities, will deposit some of these on the goods over which they pass. For this reason, as soon as the fire-gases in a continuous kiln reach a temperature of 150° C. they should be taken direct to the main flue and chimney. The amount of heat then left in them is very small, and its loss is unimportant compared with the damage which can be done by the impurities in these gases. If desired, the fire-gases may be used in a dryer, but they must be kept enclosed in flues, or pipes, and not allowed to come into contact with the goods or they will produce *scum*.

As it is, in practice, inadvisable to use the fire-gases of a continuous kiln in heating the freshly set bricks up to 120° C., some other source of heat must be used. At present three such sources are available:

(*a*) Wicket fires may be built or stoves may be placed in the door-gap of each chamber or connected to the feed-holes in the roof. In this way the heat from a separate fire is used to warm a large quantity of air. The disadvantage of this arrangement is that the products of combustion of the fuel mix with the air and sometimes discolour the goods.

(*b*) Air may be drawn over the goods which have finished firing and which are cooling in the kiln. This air is heated without any contact with fuel and is, therefore, free from the disadvantages just mentioned in (*a*). The amount of heat available is, however, limited by the rate at which the goods can be cooled and by the finishing temperature of the kiln. So far as it can be used this is the best source of hot air, but it seldom yields sufficient unless supplemented by heat from other sources.

(*c*) Air may be drawn through special flues above the arch of the kiln or below the floor, its temperature being regulated by the speed at which the air travels and the number of flues used for this purpose. Heat withdrawn in this way from the kiln must, in part at least, be replaced by the combustion of a relative amount of additional fuel, but the arrangement is so convenient, and the effect of the air on the brickwork by preventing some of

the loss by radiation which would otherwise take place is so good, that it may be considered as the second best source of heat and the best means of supplementing the hot air supplied by the chambers containing cooling goods. Air drawn through special flues is, if the flues are in good condition, quite free from objectionable impurities.

The use of *wicket fires* or *stoves* needs little description, as it is familiar to most brickmakers. After a chamber has been filled with bricks the door-gap is built up, plastered with daub, and allowed to dry. If a wicket-fire is to be used, two openings must be left in the door-gap, one to feed in the fuel for the fire and another to admit air to allow the fuel to burn. Some burners

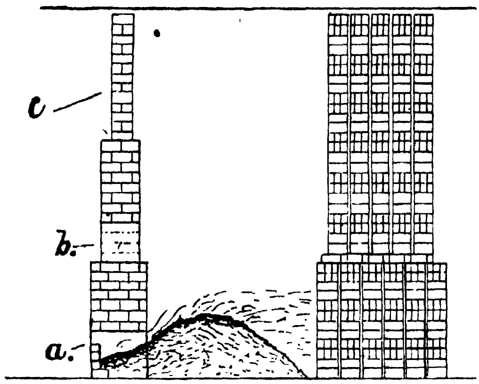


FIG. 185.—Section showing wicket-fire.

prefer to construct a small fire-box by using a grate on which to rest the fuel, but the more usual practice is to allow the fuel to burn on the ground (fig. 185).

A couple of shovelfuls of glowing fuel is now placed behind the door-gaps and the appropriate damper opened so as to connect the chamber directly with the chimney, the sides of the chamber having been, meanwhile, provided with iron dampers, or with paper pasted on to the bricks or over the openings in the walls between each chamber. The chamber is thus isolated from the rest of the kiln and is operated quite independently. The temperature inside it is slowly raised by the addition of more fuel from time to time, until the bricks are thoroughly dry and of a temperature of at least 120° C. The side dampers are then removed, the door-gap openings filled in, the damper in the next

chamber which took the fire-gases to the chimney is closed, and the newly dried bricks are thus placed in circuit with the rest of the kiln.

In some cases it is easier to have a portable stove to hold the fuel and to fit the exit pipe of this to the door-gap of the chamber to be dried, or to one of the feed-holes in the roof. Opinions differ considerably as to which is the best arrangement, and the author has made a considerable number of tests to solve the problem. He has found that if the bricks are very damp it is better to use a stove supplying heat near the floor of the kiln and to open several feed-holes in the roof so as to allow the steam and gases to escape in an upward direction. If, on the contrary, the goods are not particularly damp they can be dried more evenly and rapidly by using several stoves supplying air through the feed-holes in the arch of the kiln in a downward direction.

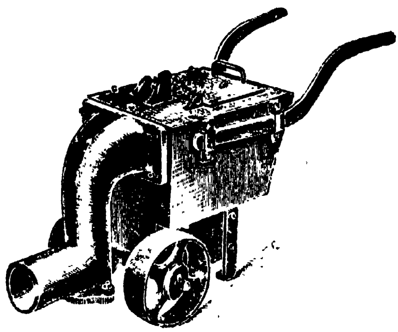


FIG. 186.—Portable stove.

A convenient stove for use on the ground level is shown in fig. 186. It consists of a grate enclosed in an iron chamber and in many respects resembles a slab-heater (p. 163) but is smaller and portable.

A stove (fig. 187) for placing in the feed-holes of a continuous kiln consists of a cylinder about 12 to 18 in. high, its lower diameter being slightly less than that of the feed-hole. The fuel is placed on the grate and the heated air passes down into the chamber beneath. Several such stoves should be used at a time, their number and position depending on the rapidity with which the bricks can be heated (fig. 188).

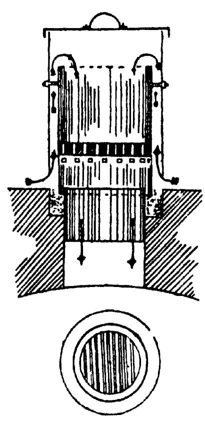


FIG. 187.—Stove for top of kiln.

Cooling chambers are usually made to supply hot air by either temporary or permanent flues. As the air entering these chambers becomes heated it rises, and such flues are, therefore, usually placed near the top of the kiln. For temporary flues this is the best position, but permanent ones should be built as low as

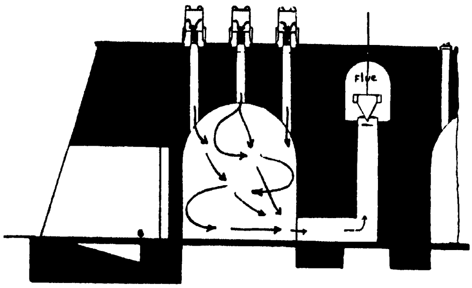


FIG. 188.—Top stoves in use.

possible in order to counteract the tendency to leakage caused by the greater movements of the upper parts of the kiln.

Temporary Flues are usually made of sheet metal with an elbow at each end. They are employed to connect the feed-holes of one of the cooling chambers with those of one newly filled, but

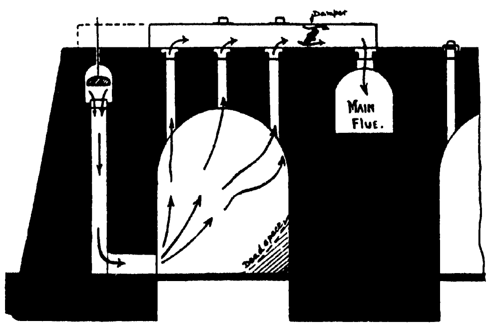


FIG. 189.—Temporary flue in use.

as these chambers may be a considerable distance apart it is advantageous to construct a permanent flue the whole length of the kiln, and to connect this by means of two separate temporary pipes to the cooling and warming chambers respectively. It is then possible to avoid the elbows on the connecting pipe and to make it as shown in fig. 189.

Some burners prefer to cover four feed-holes, and for this pur-

pose provide a square, bottomless box at one or both ends of the connecting tube.

The chief objection to temporary metal flues is the serious reduction of the temperature of the gases passing through them owing to the loss of heat by radiation. A minor difficulty is the tendency of the warm air to remain in the top of the kiln, instead of distributing itself evenly as it does when introduced near the bottom of the chamber.

Permanent Flues are constructed of brickwork and are an integral part of the kiln. The loss of heat by radiation is much less than with metal pipes, but the chance of leakage is much greater, particularly if the flues are in the upper part of the kiln where the movement due to expansion and contraction is greatest.

One of the earliest arrangements of permanent flues for the supply of hot air is that devised by Dannenberg, and shown diagrammatically in fig. 190 in which A represents the cooling

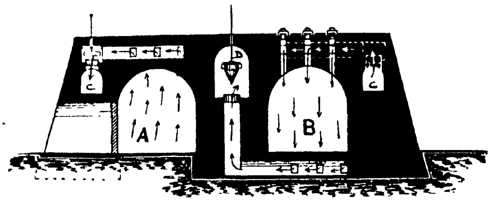


FIG. 190.—Dannenberg's kiln.

chamber and B the one to be heated. Air enters chamber A through any suitable opening and becoming heated it rises, passes through a series of openings in the roof, and through a transverse flue to the main hot-air duct (*c*). It passes along this till it reaches a point near to chamber B, where it enters another transverse duct and is drawn down through openings in the roof of the chamber, passing out through the floor and the main flue D to the chimney. It is convenient to use the feed-holes as openings in the roof of the chambers, but care must be taken that no coal enters the cross flues.

Owing to the tendency of hot air to distribute itself badly through a chamber to be heated in this way, better results will be obtained by the addition of a down-take flue connecting the main hot-air duct with the bottom of the kiln. The arrangement in fig. 191 shows this down-take flue.

A better means of supplying hot air is that used in the "Vaughan" kiln (fig. 192) in which a flue is constructed immedi-

ately over the arch into which the air heated by its contact with the bricks in chamber A rises and passes to the centrally situated flue running the whole length of the kiln.

The hot air next passes through the down-take (also centrally situated) and under the floor of the chamber B, through the perforations in which it rises, and after drying and warming the

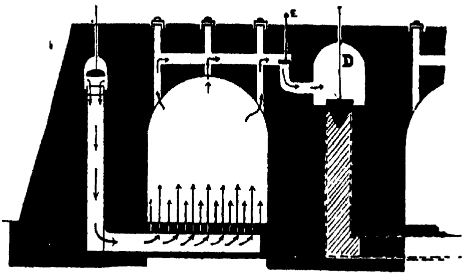


FIG. 191.—Spitta's hot-air flues.

bricks is taken to the main flue. The temperature of the air entering chamber B can be regulated by the amount allowed to pass down the down-take, and by admitting cold air through the external "cold-air valve," placed at the left of the chamber. This is very valuable when heating delicate clays. Hot air can be used for aiding combustion by supplying it to the fuel on the grates, as well as for warming newly set goods.

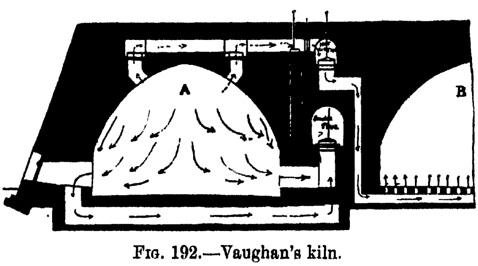


FIG. 192.—Vaughan's kiln.

A similar arrangement, but using arched flues instead of a flat one, is used in the "Manchester" and "Staffordshire" kilns (fig. 193), but in these the hot air is collected through more openings and conveyed to a much larger central hot-air flue, which is situated in much the same place as that occupied by the "smoke flue" in fig. 192, about 6 ft. 6 in. above the floor

level. This flue is so placed that it is unlikely to be disturbed by the movement of the kiln during heating and cooling, and consequently it is not liable to leak. In both these kilns the hot air is taken by a flue leading from the bottom of the hot air flue (damper controlled) down the centre wall, and admitted through an opening in line with the grate at the end of the chamber, either over or under the bars. This, alone, is used for

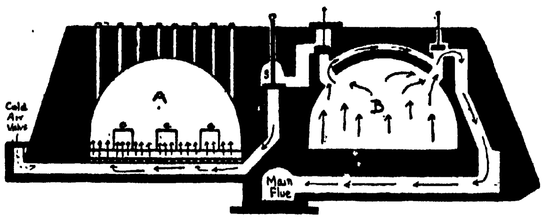


FIG. 193.—Flue arrangement in "Manchester" and "Staffordshire" kilns.

starting the fires, and afterwards the hot air from this flue, supplemented by air of atmospheric temperature, may be used for combustion purposes. The hot air is also admitted through openings in the top of the chamber, at points where, in practice, the vapour has shown any tendency to linger, and thus secures thorough circulation in every part of the chambers for drying. The moist gases formed during the stoving, and the combustion

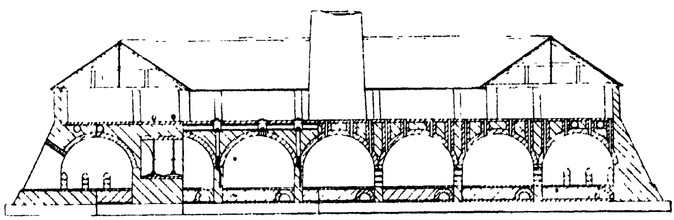


FIG. 194.—"English" kiln.

gases afterwards, are carried through (1) a damper-controlled flue leading from an opening in the outer wall of the chamber, and thence under the floor to the central large smoke flue, and (2) through openings into a flue running right across the centre of the chamber, with separate connexions to the main smoke flue.

Slight modifications of the foregoing arrangements of flues are used by several other firms; a particularly ingenious system being employed in the "English" kiln used by the London Brick Co. at Fletton (fig. 194). In this, two hot-air flues run along the top

of the kiln, each being provided with a down-take to each chamber and an opening into the top of the chamber. These openings are controlled by flat valves, and the whole construction is such that no special valves are needed for the hot air as distinct from the steam-exit flues. This kiln is, however, designed for burning only common bricks.

Instead of heating the air in the upper part of the kiln it is taken from below the floor in Brown's patent kiln, special flues (as *a* in fig. 184) being arranged for this purpose, so that the heated air may be used to supplement that from the cooling chambers in drying or warming the bricks, or it may be used to facilitate the combustion of the fuel on the grate.

Chamber Kilns.—The down-draught principle has been applied to continuous kilns by several patentees, with a view to obtaining a better colour on the goods than is possible with the original Hoffmann kiln. Broadly speaking, all continuous kilns employ grates for the fuel work on the down-draught principle, though it is only in special instances that a bag- or flash-wall is erected between the grate and the goods to be heated. It is also more convenient for ordinary red bricks to remove the gases from the side rather than from below the sole of the kiln; but these variations are only slight, and a careful study of the directions in which the heat travels in a modern continuous kiln will soon show the preponderance of an up- and down-draught, or as it is usually termed a "down-draught". This is particularly the case in continuous kilns fired by gas.

The advantages of the down-draught principle in single kilns have already been mentioned; the most important are evenness of heating, excellence of colour of the goods, and economy in fuel consumption. When applied to a continuous kiln this last advantage is enormously increased whilst the others are retained, and for this reason continuous kilns in which this principle is largely used will be found to be best for facing bricks, tiles, terra-cotta, and other work where colour is of importance and the output required is large.

In order that the down-draught principle may be effectually applied it is necessary to divide the tunnel of the kiln into a number of chambers by means of partitions permanently erected in the kilns—whence the name "chamber" kilns. Various forms of partitions have been patented (especially on the Continent) but they may all be classed under one of the following heads:—

(*a*) Solid walls with no openings.

(*b*) Walls with openings uncontrolled by dampers.

(*c*) Walls with openings controlled by iron, fire-brick, or paper dampers.

Solid partition walls having no openings in them to the next chamber, are claimed to have been first introduced by several different persons, and the true originator is unknown. In most cases the connexion between the chambers is made by flues under the walls—a method which is open to the objection of great friction in the passage of the gases, as it is difficult to construct such flues of a sufficient size without enormously increasing the cost of the kiln. This method of separating the chambers is not much used in England but on the Continent it has met with considerable favour. British brickmakers prefer to use small underground flues for the supply of hot air, and to leave openings in the partition walls which can be closed by dampers when required.

Iron dampers are easy to place in position when new, but are apt to warp and become troublesome after some time, so that paper dampers are often preferred for partition work.

Fire-clay dampers are excellent, if properly designed, but are heavy to handle. Some good types have been used in kilns working as high as cone 17. A satisfactory damper may be made of slabs 12 in. high and 2 in. thick, the iron bolts holding them being placed in the centre and so fully protected from the heat.

Paper dampers consist of sheets of suitable paper pasted over the openings with a little clay slip to which some dextrin has been added, and in addition to being very cheap and easy to fix, they have the advantage of removing themselves automatically when the kiln is sufficiently hot to burn them.

The paper used should be sufficiently thin to be cheap, but must be as free as possible from pin-holes. A light grade of brown paper is usually best, being stronger than newspaper and, if carefully selected, less porous. It can usually be obtained in rolls of a convenient size weighing 1 cwt., and measuring 40 to 75 in. wide.

Toughness and resistance to water are necessary, as otherwise the paper would tear readily and the damper might break at a critical moment if sodden with condensed moisture from the bricks. When the openings to be covered are too large for a single piece of paper, the pieces used should overlap by 2 in.,

the joints being well fastened with flour-paste, as leaky joints are a frequent source of trouble.

Further details as to the use of these dampers are described in the section on "Setting".

The use of permanent partition walls greatly improves the quality of the bricks produced, and enables the chambers to be worked more or less independently when the supply of bricks is irregular, but kilns in which such walls are employed cannot be so economical in fuel as the original Hoffmann kiln, as the heat spent in raising the temperature of these walls is entirely wasted. Many attempts have been made to substitute portions of the walling by various other materials with greater or less success. The most satisfactory method is to leave considerable spaces in the walls, and cover these by dampers, which can be destroyed or removed when it is no longer necessary to shut off a chamber from the rest, as when its contents have attained a temperature

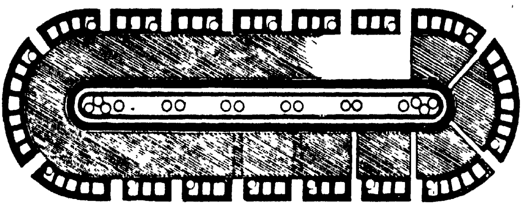


FIG. 195.—Beyer's double paper-damper.

exceeding 120° C. When very wet bricks are to be dried in the kiln, two paper-dampers may be used with an air-space between them, as suggested by F. Beyer, and working as follows :—

Instead of setting the new bricks close to the paper-damper, as at present, two blades of bricks are omitted, leaving a space of about 2 ft. (fig. 195) which is only filled when the smoking of the chamber is complete. When the chamber is filled, paper-dampers are fixed to each end of the blades of bricks, and as there is a space of 2 ft. between these dampers there is ample room for the burner to step in and examine them as to their tightness during the smoking, and to repair them if necessary.

As a current of air plays on one side of the paper, this resists the action of the heat and the moisture much better than the ordinary form of paper-damper, which is equally heated on both sides, and prevents it collapsing before the proper time.

When the chamber is completely smoked and ready to be put into the direct round of the kiln, the space between the dampers

is filled with bricks which have been previously dried, or it may even be left empty, if preferred, without in any way interfering with the working of the kiln, providing the outer wall is bricked up. The accompanying diagram (fig. 195) shows the position of the papers, as well as the portions of the kiln filled up with dry bricks, and included in the regular run of the firing.

Steam is produced in large quantities in most kilns, as it is seldom that all the water is dried out of the bricks. This is particularly the case with bricks made by the stiff-plastic process and set direct into the kiln; many of these will lose one-seventh of their weight on burning, and the greater part of this loss will occur below a red heat. For this reason the removal of steam is an important feature of all the best continuous kilns, and they contain special arrangements for this purpose.

As already pointed out, it is usually necessary to use some supplementary method of heating, such as hot air, or wicket-fires, to remove moisture from the goods and to raise their temperature to at least 120° C. During this heating large volumes of steam are produced, and if these come into contact with cooler bricks condensation occurs and the bricks may be spoiled. It is therefore essential to remove the steam as rapidly and completely as possible after it has been produced.

A common method of doing this is to open the feed-holes in the chamber in which the steam is formed, so that it may escape through them, but this is only a rough-and-ready method and unsuitable for many purposes, and in the better kilns some system of steam-flues is provided.

When unusually dry goods are being fired, the opening leading from each chamber to the main flue may be used, but for wet bricks this is too small, or so far removed that condensation would occur in the bricks in the remoter parts of the chamber, and subsidiary flues are then essential.

The position of these flues depends upon the direction in which the heat and steam are expected to travel, some burners preferring it to travel upwards and others downwards. The former use wicket-fires or stoves (figs. 185 and 186) near the ground level, or introduce warm air from other parts of the kiln to below the floor of the chamber to be warmed (fig. 191), whilst others use portable stoves fitting into the feed-holes in the roof of the chamber or flues which introduce warm air at just below the top of the arch (fig. 187), and others again introduce the heat at or near the ground level and withdraw the steam at the same

level, a sufficient number of flues being used to carry off the steam to the main flue (figs. 196 and 197).

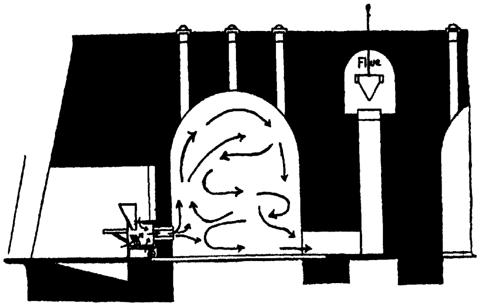


FIG. 196.—Drying and removing steam at one level.

It is essential that some construction be chosen which will permit the heat in the chamber to be distributed as evenly as possible and will avoid large "dead spaces," though some amount of dead space (fig. 189) is unavoidable in almost every kiln.

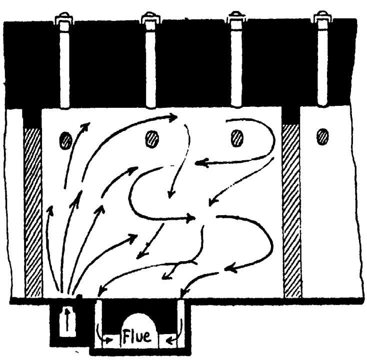


FIG. 197.—Drying and removing steam at floor level.

A simple form of steam-flue (fig. 198) may be constructed by building a flue under the kiln floor and connecting it to a small flue in the outer wall of each chamber, and controlled by a flat sliding damper (*a*). The main flue (*b*) is, in this case, shown in the centre of the kiln.

W. H. Sercombe, in the kiln known by his name (fig. 199), uses a similar construction for the main fire-gases, but provides, in addition, one or more steam outlets in the upper part of the kiln above the arch, so that each chamber has four or more steam outlets.

In the "Manchester," "Staffordshire," and Vaughan kilns also, the steam can be taken out from above or below, or both, as desired (see pp. 275 and 298).

The value of a flue-system for removing the steam may be judged by the shortness of the distance the steam has to travel before it is removed from the chamber. When hot, steam is lighter than air and may best be removed from the top, but when near the condensation point it should be taken away from near the bottom of the chamber, hence two sets of openings or flues are needed for its efficient removal.

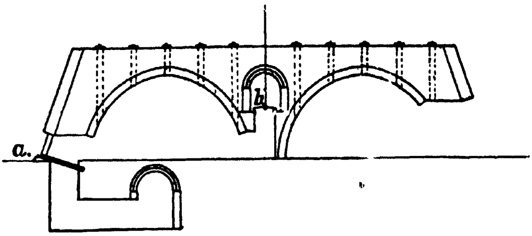


FIG. 198.—Diagram of steam-flue.

The *draught* of a kiln is usually produced by means of one or more chimneys, and providing these are of ample size and are in good order their use is satisfactory for most brick-yards. Chimneys are, however, subject to variations in drawing power owing to climatic changes, and it is sometimes difficult to work steadily with them.

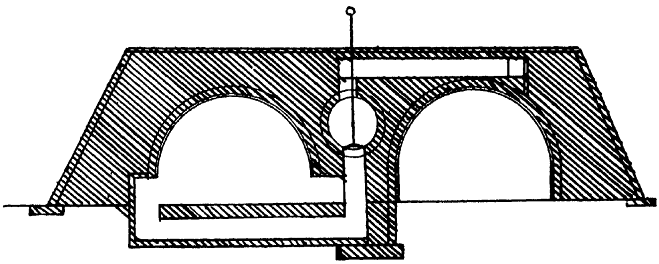


FIG. 199.—Sercombe kiln.

In an ideal chimney the weight of gases drawn through it varies as the square root of its height, i.e. each added unit of length increases the draught, but to a less extent than its predecessors, so that by doubling the height of a chimney the weight of air drawn is only two or one and a half times the original amount.

If the sectional area of the chimney is increased proportionately, so as to double the cross-section, the draught is doubled.

Unfortunately it is not usually possible to enlarge the area of a chimney without first pulling it down.

The temperature of the gases passing through the chimney is increased until a mean internal temperature of 300° C. is reached. Above this temperature the velocity of the gases does not increase with increase of temperature, and there is no advantage to be gained by allowing gases to pass to the chimney at a higher temperature than will give this average inside the chimney.

A thermometer placed at the base of the chimney, and read occasionally, ensures the prevention of waste heat passing to the chimney in unnecessarily large quantities. As the gases at the base of a chimney are hotter than those at the top this thermometer should never indicate a temperature of 500° C., and lower temperatures are better if the temperature at the top of the chimney can be ascertained and the mean internal temperature calculated therefrom.

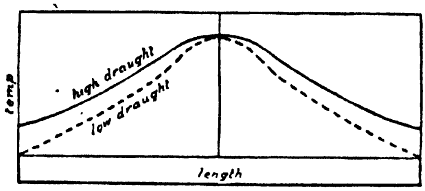


FIG. 200.—Diagram of chimney draught.

When a fan is used, the gases may be cooled to 150° C. (but not lower) so that the advantage derived from the use of a fan lies chiefly in its ability to create a greater and steadier draught rather than in its actual economy of working as compared with an ideal chimney. Unfortunately few brickworks' chimneys approach the ideal.

In an ordinary single kiln the products of combustion are cooled by the bricks to be burned until these attain a high temperature, when the gases escape in a heated condition. Such conditions are more favourable to a chimney than to a fan, unless the gases are passed into another kiln or a dryer.

In a continuous kiln, on the contrary, the object of the burner is to use all the available heat in the gases, and a fan is then preferable, as otherwise an abnormally high chimney would be required to obtain the best results. J. W. Cobb has shown that the effect of using chimney draught, and mechanical draught on the same kiln may be shown diagrammatically as in fig. 200, in which

the dotted line marks the assumed distribution of temperature along the length of the kiln when the chimney is producing the draught. On putting a fan into use and raising the draught the quantity of air drawn is increased, and in order to neutralize the cooling effect of the excess of air the rate of feeding in the coal must be also increased. Two effects follow: in the first place the temperature curve is flattened; this necessitates more chambers in use, and shows that the usable draught is limited by the number of chambers in the kiln. In the second place the peak of the temperature curve travels more quickly along the kiln, the chambers are burned more quickly, and the output increased. The increase in output can be effected with economy by increasing the draught until the limit is reached which the size of the kiln determines; beyond this, higher draught means waste of fuel. It would be wrong to apply a fan to increasing the output of a kiln which has already as few chambers as will work well with natural draught, but by increasing the draught up to the maximum so determined, economy is effected, because the radiation and conduction losses from the kiln remain constant, and so can be made to bear a smaller ratio to the total heat used.

Bührer has made excellent use of this principle in connexion with the kilns of his name (fig. 208).

For the reasons just given, in the case of continuous kilns, *mechanical draught* is replacing that obtained by means of a chimney and (erroneously) termed "natural" draught, a fan being substituted for the chimney. When rightly designed and properly cared for, fans give a more powerful draught and one which can be more easily and accurately regulated even in the windiest weather, and the result of this steadier working generally leads to a considerable economy in fuel, because there is no "waiting" until a sufficient draught is produced, as is frequently the case with a chimney. They also cost less to construct than a chimney, but this advantage is to some extent neutralized by the cost of driving them, though the difference in running cost between a fan and a chimney is not so great as is popularly supposed.

Owing to the general structure of continuous kilns an induced draught fan is preferable to a blower. Several fans very suitable for brick-burning are now on the market, the best known being those made by Matthews & Yates, Ltd. (fig. 201); Sutcliffe Ventilating and Drying Co. (figs. 202 and 203); Sturtevant Engineering

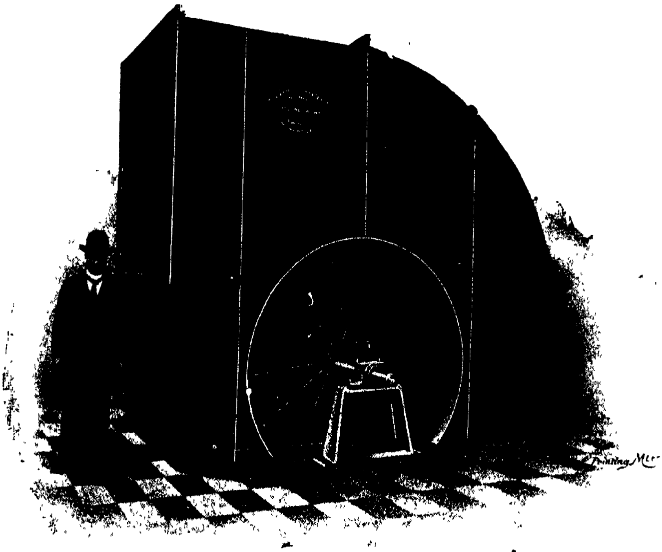


Fig. 201.—Matthews & Yates fan.

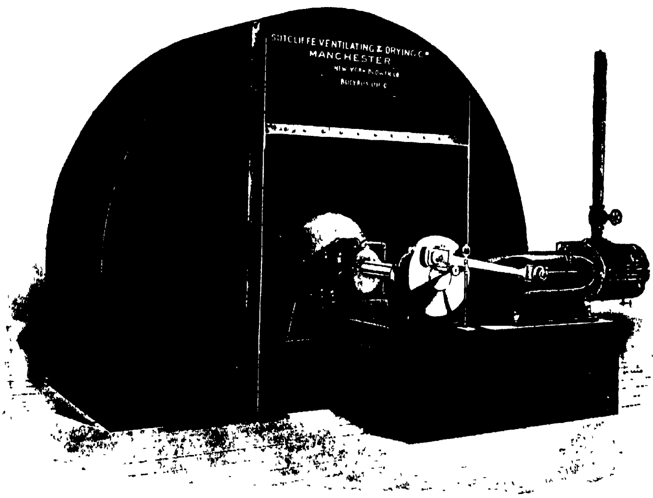


Fig. 202.—Sutcliffe fan.

Co., Ltd. (fig. 204); James Keith & Blackman Co., Ltd. (fig. 205).

The speed at which a fan is run should not be greater than that necessary to produce the required draught, as the power required to drive it increases as the cube of the speed. That is to say, if the speed is doubled, eight times the power is required, or if the speed is trebled, twenty-seven times the power would be necessary. In other words, small fans at high speed are not as economical as larger fans revolving more slowly. From this it follows that the best size of fan is one which at the lowest speed will be sufficiently large to produce the necessary draught in the kilns. Fans with inlets on both sides are generally considered to be better than those with one inlet only, but

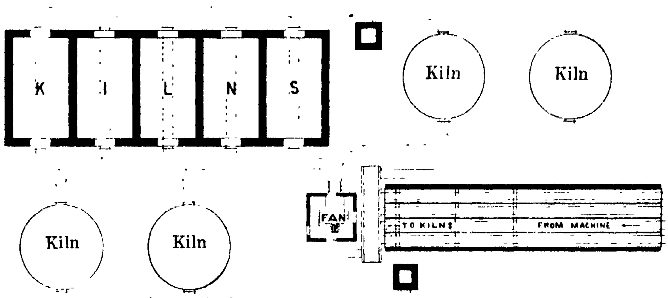


Fig. 203.—Plan showing connexion of fan, kilns, and dryer.

the difference is not very great if the fan is properly designed, well mounted, and of sufficient size.

The construction of the fan should be as simple as possible in order that it may not easily get out of order, or cause unnecessary delay in waiting for special repairers; but the designing and erection of both chimneys and fans must, to a large extent, be left to those accustomed to this kind of work, for the experience necessary to successful working is only obtained as the result of years of practical application.

It is always wise to install two fans and to run them alternately, so that in the event of a breakdown the second fan may be available, though in a good continuous kiln little or no damage will be done before the fan can be repaired if only one is used, providing the dampers of the kiln are kept closed. The fans may be driven direct from a small engine attached to

them (fig. 206) or a belt may be used. The separate engine has the advantage that it can be run at night and on Sundays

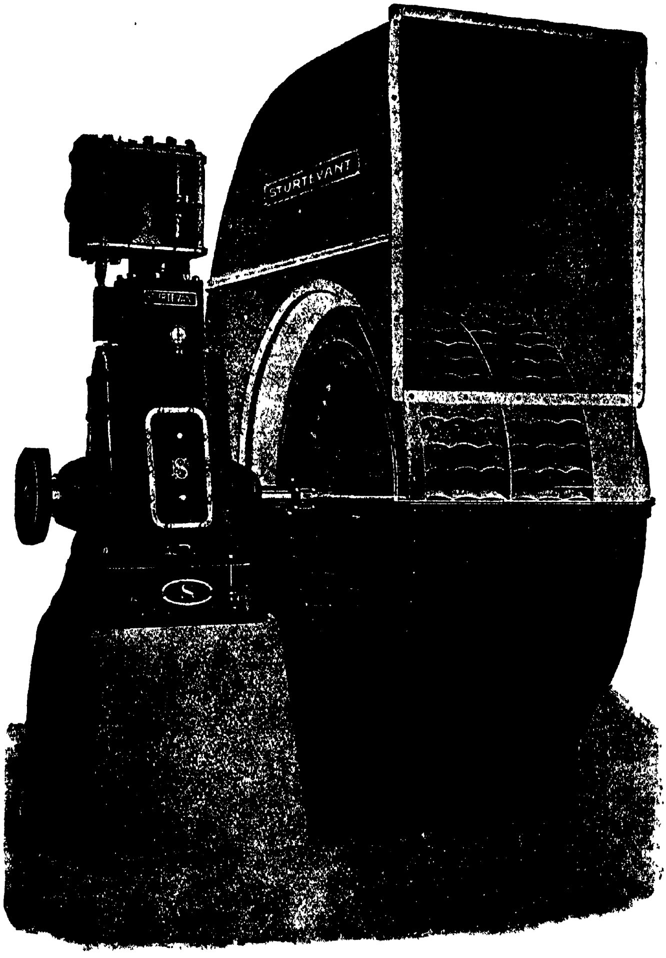


FIG. 204.—Sturtevant fan.

and holidays without the necessity of keeping other machinery in motion. On these occasions they are looked after by the burners.

Fans can be worked without any chimney, but it is better to

allow them to discharge their contents into a short stack, or, if preferred they may discharge into the tubes or flues of a dryer, though when this is done care must be taken that the gases do not come into contact with the goods to be dried or the bricks may be discoloured.

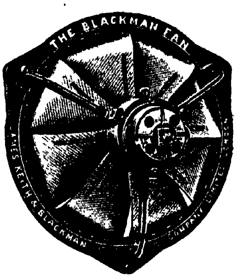


FIG. 205.—Blackman fan.

Fans are largely composed of metal; they must not come into contact with very hot gases, though a temperature of 200° C. will seldom do much harm. Unless it is unusually short no continuous kiln should discharge its gases at a higher temperature than this. With single intermittent

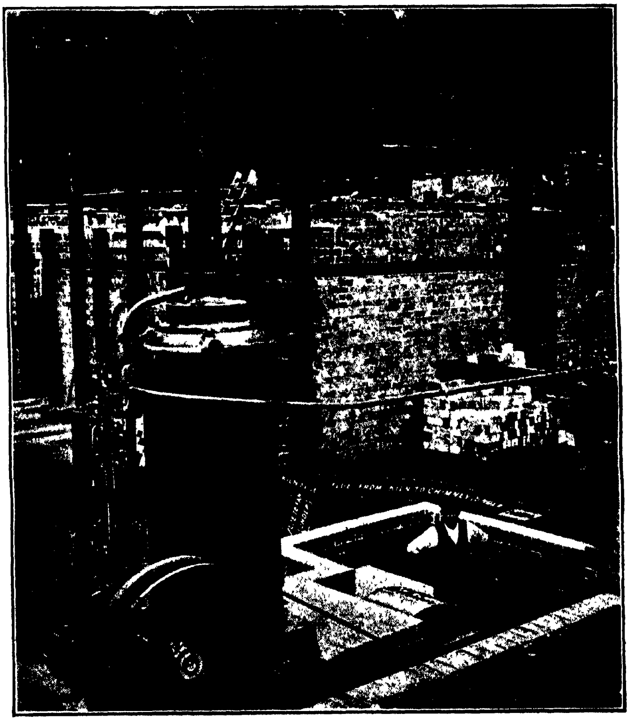


FIG. 206.—Sutcliffe's self-contained engine, boiler, and fan.

kilns the gases may first be drawn through a dryer (fig. 207).

The increased draught obtainable when a fan is used enables the firing to be carried out more rapidly, and in some cases more than thrice the normal output of a kiln may be obtained by this means. Some of the best work in this connexion has been done by Jacob Bührer, of Constance, who regularly burns at the unusual rate of 4 linear feet per hour in his patent kiln. As such a rapid rate of burning demands a great length of kiln or fire-travel, it is necessary to make each chamber correspondingly narrower than usual, and to avoid any inconvenience caused by

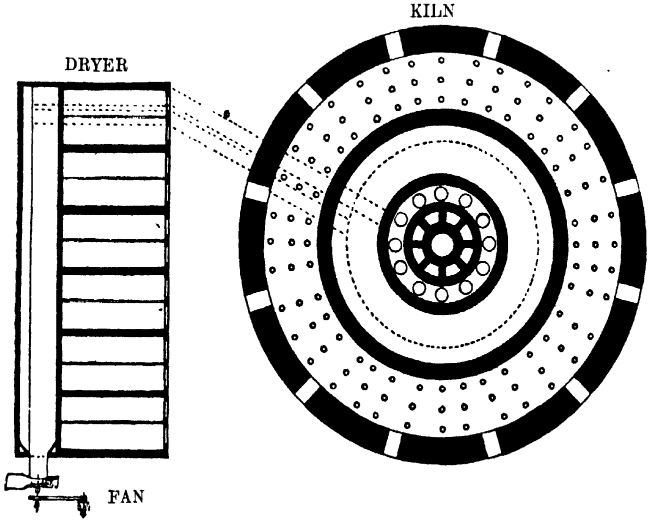


FIG. 207.—Kiln connected to dryer.

the unusual length of kiln if it were to be built on the usual plan, Bührer arranges his chambers as shown in fig. 208.

This enables him to work with a large number of chambers (on a length of 25 yds.) in each section—steaming, full fire, and cooling—and so produces excellent results even with many delicate clays, though his kiln is best adapted for sandy clays of an open texture. A typical brick-plant worked on this system has a kiln tunnel 2 yds. wide, $2\frac{1}{2}$ yds. high, and 100 yds. in length, and an artificial dryer comprising twenty chambers, 7 yds. long, 2 yds. wide, and $2\frac{3}{4}$ yds. high, the draught controlled by a fan utilizing 10 h.p. running night and day, and produces 10,000,000 bricks annually.

The dryer is placed near to the kiln, so that heat radiated from the latter may be used in the former.

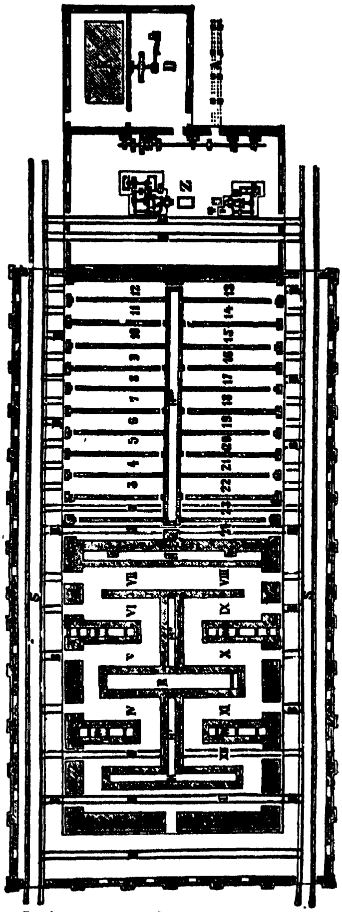


Fig. 208.—Plan of Bührer's kiln and dryer.

J. Osman & Co., Ltd., have recently introduced a similar kiln termed the "Excelsior" (fig. 209), for which they claim an output of 120,000 bricks per week in a kiln measuring only 66 ft. by 60 ft. the capacity for increased output without structural alterations, and that it is cheaper to erect than any other continuous kiln on the market though at the time of writing no kiln of this design has been built.

There is no reason to doubt that as soon as British brickmakers have realized the advantages to be derived from the use of mechanical draught, they will employ fans in place of the present chimneys; for continuous kilns the firms who have already overcome the trifling difficulties which occur when any change of method is used in a works are highly satisfied with the improvements and economies resulting in the use of draught produced by a fan. Quite apart from any other consideration, the increased regularity in the heating of the kiln is more than sufficient to pay for the installation of a suitable fan.

Some firms have met with difficulties owing to their fans getting out of order. These arise most frequently when only one fan is used, and for this reason two should be installed and run alternately, or one may be used for the boiler fire and the

other for the kiln if each is capable of taking care of both in case one fan should get out of order. It will then be found that the difficulties experienced in the use of fans will be less than the damage done to bricks by the climatic effects on a chimney and by having to let the kiln "soak" because the wind is in the wrong quarter.

Having thus outlined the main features of the best modern continuous kilns, five typical ones may be described. The first is a modern Hoffmann kiln in which the main features of the original pattern are retained, but which has been altered in shape. This is suitable for common bricks.

The second has given remarkably satisfactory results in the

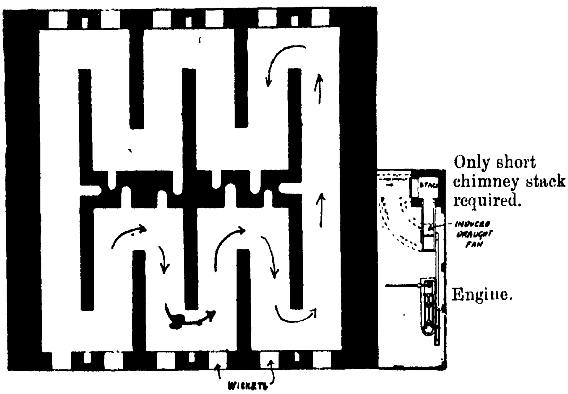


FIG. 209.—Plan of Osman's "Excelsior" kiln.

production of best facing bricks where colour is of great im portance. This kiln may also be used for fire-bricks and othe goods requiring a high temperature. It is a typical *chamber kiln*

The third is a kiln specially designed for burning blue brick and has proved highly satisfactory for this purpose.

The fourth is a tunnel kiln in which the goods travel along i cars, the various parts of the kiln each remaining at a definit temperature.

The fifth is a gas-fired kiln.

In thus selecting one design in preference to others th author's sole aim has been to choose the ones which, in hi opinion, contain the best features and fewest objectionable quali ties. He holds no brief for the particular kilns described and ha no financial interest in their success, but having found then

succeed where others have failed, and having studied all the best-known kilns with equal care, he has selected these as representing, in his mind, the simplest and best design for the purpose yet published. Those brickmakers who are interested in other kilns may compare them with the ones described with considerable interest.

A modern continuous kiln with sixteen chambers, for producing common bricks, is shown in figs. 210 and 211. This kiln is

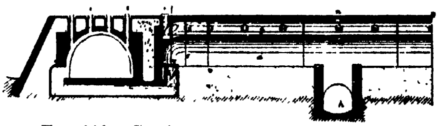


FIG. 210.—Section of modern Hoffmann kiln.

the one last recommended by Frederick Hoffmann, though there are numerous variations of this design used in different works. It consists of an elongated, endless tunnel or "ring" in which the bricks to be burned are placed, and a central body of masonry fitted with flues connected to a chimney-stack.

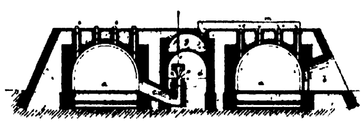


FIG. 211.—Cross section of modern Hoffmann kiln.

In former times only twelve chambers were used, and the kilns were circular in pattern, but these are too short, and the shape shown in fig. 212 is now almost universal. This pattern of kiln can be built for any desired output from 500,000 bricks per annum upwards.

In the Hoffmann kiln (figs. 210 and 211) the chimney is usually placed near the centre, each part of the tunnel being connected to it by means of small flues discharging into a central main flue, which in its turn discharges into the chimney.

These flues are represented by dotted lines in fig. 212, in which the chimney is built outside the kiln so as to avoid the necessity of so massive a block of masonry within the kiln itself. The older types of Hoffmann kiln (fig. 182) had all the flues arranged on the central wall of the kiln, but in the one shown two flues are arranged for each chamber at the end of the kiln—one on the outer wall, and one in the inner masonry. The additional flue is useful in reducing the friction of the flue-gases and in distributing the heat more evenly in these parts of the kiln (in-

cidentally it may be noted that W. H. Sercombe uses this arrangement in each chamber and not only at the ends).

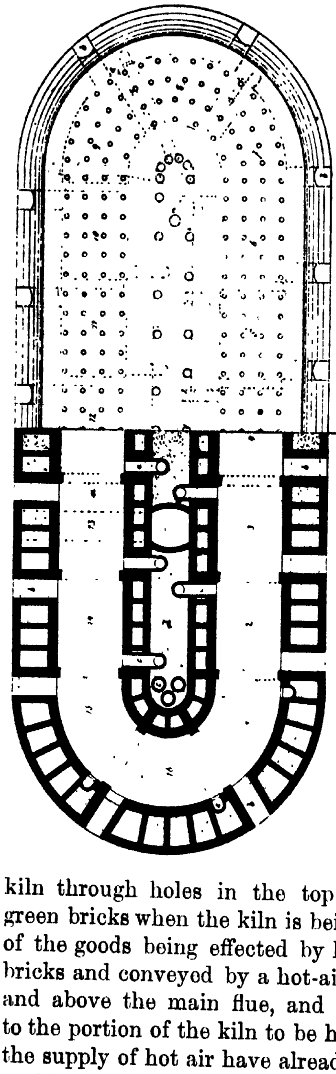


FIG. 212.—Plan of modern Hoffmann kiln.

These flues are controlled by conical dampers to which are attached vertical iron rods operated from the top of the kiln. The extent to which the dampers are opened is usually regulated by a board or "horse" with holes in it, pegs fixed in the holes passing through a ring at the other end of the damper rod. This arrangement is clumsy, and far easier regulation is obtained if the damper-rod is surrounded by a collar as shown in fig. 213 working on a hinge in such a manner that on lifting, the rod can be raised easily, but it will not sink unless the collar be kept perfectly level by depressing the "step" on the other side of the hinge with the foot. Damper-rod holders of this type can be obtained very cheaply from T. Burnett & Co., Ltd., Doncaster.

The fuel is fed into the kiln through holes in the top into hollow pillars formed of green bricks when the kiln is being set, the preliminary warming of the goods being effected by hot air drawn from the cooling bricks and conveyed by a hot-air flue in the centre of the kiln and above the main flue, and by a temporary metal flue (m) to the portion of the kiln to be heated. Other arrangements for the supply of hot air have already been described (p. 272).

The kiln is provided with sixteen wickets or door-gaps through

which the goods enter and leave the kiln. These wickets are built up as soon as the portion of the kiln nearest to them has been filled. As it is essential that no air should leak through these, the brickwork used to fill them is thickly plastered with clay paste or "daub".

The fire travels steadily forward around the kiln, the gases passing through a sufficient number of bricks to utilize the greater part of the heat they contain, and the heat from the finished bricks being utilized to dry freshly set ones by means of the hot-air flues already described.

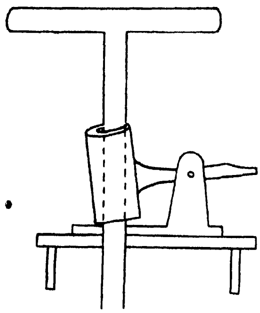


FIG. 213.—Clamp for damper rod.

As originally designed, no hot-air flue was used in the Hoffmann kiln, though few are now built without some means of using the hot air from the cooling chambers. J. Osman & Co. claim that the use of this hot air in their kiln "effects a saving of 40 per cent of fuel over and above the ordinary (i.e. original) Hoffmann kiln," and other modern kiln-builders make similar statements, but the saving effected is the result of several factors and not merely to the use of hot air. The Osman "New Perfect" kiln is practically a Hoffmann kiln similar to the one shown in figs. 211 and 212, but the hot air is conveyed through permanent hot-air flues placed in the upper part of the kiln instead of through temporary ones, in a manner similar to fig. 189, except that the hot-air flue is placed centrally in the kiln and the main or smoke flue is below the ground level on the circumference of the kiln. As already pointed out, the weakness of this arrangement is the liability to leakage due to the movement of the kiln, and to avoid this J. Osman & Co. are now placing their hot-air flue much lower than formerly, and are admitting the air to the bottom of the chambers to be warmed, its steam escaping through an up-draught flue connected to the main flue.

The progress of the fire depends upon the speed at which the clay can be heated and cooled; the usual rate is 6 in. to 1 ft. per hour, but if the kiln is sufficiently long and well managed double this rate should be reached with normal clays. By the use of a mechanical draught J. Bührer is able to use a rate of

fire-travel four or five times as fast as that usually employed (p. 288).

The tunnel should be as long as possible, the width being not more than 16 ft. and preferably much narrower.

The walls and other masonry must be strong and well built of good materials. Several kilns known to the author are scarcely fit to use, though they have only been erected a few years, through failing to comply with these requirements. Brickmakers should remember, in comparing tenders for a kiln, that the cheapest is often the least durable.

For ordinary use the kiln may be built of any good bricks, but for unusually high temperatures a fire-brick lining is necessary. The arches and door-jambs should be built with special made arched bricks and bull-noses respectively. The foundation of the kiln must be dry, or a special bed constructed, as a damp floor causes a great waste of fuel.

The upper part of the tunnel or ring is usually arched (as shown), but it may be replaced by a temporary layer of ashes if required. The arches add considerably to the cost of erection, but are permanent; the ash-layer top costs but little, but must be renewed each time a chamber is filled. Hence for temporary work an "archless" kiln is to be preferred, but if the kiln is to be used for several years the usual form will prove to be more satisfactory, especially where better class bricks are required.

The construction of archless kilns of the semi-continuous type was patented by Bull in 1876 and of the continuous type by Bock (in Germany) in 1896. The first of these has long been used in India and China, in spite of several disadvantages involved in the use of the movable chimneys it employs.

Several British patents have been taken out for "archless" continuous kilns, one of the most satisfactory being that of H. Harrison, Manchester. In this kiln the door-gaps or wickets are sufficiently wide for a horse and cart to enter, and the bricks are loaded direct. As the ash-layer forming the roof can be removed in a few minutes the kiln can be emptied easily and rapidly, as it cools more readily than the arched form. When a new chamber has been filled with bricks a layer of burned bricks laid close together is placed on the top, the usual "pot" holes being left for feeding in the fuel, and the whole is covered to a depth of 4 in. to 6 in. with ashes.

The cost of this work is very low, as it can be done by two boys who can also do other work in the intervals. The comple-

tion of the firing of any part of the kiln can be seen by that portion of the "roof" being lower than that on the insufficiently fired portions.

The Harrison kiln also differs from the ordinary Hoffmann kiln in the disposition of the flues, the main flue running along two sides of the kiln (as in fig. 220) instead of down the centre, and in the use of a fan.

All continuous kilns should be covered with a wooden and glass roof, the space between this and the kiln being match-boarded and fitted with doors for ventilation. The roof not only affords ample protection for the workman, but, by keeping the fuel and top of the kiln dry, it reduces fuel consumption and

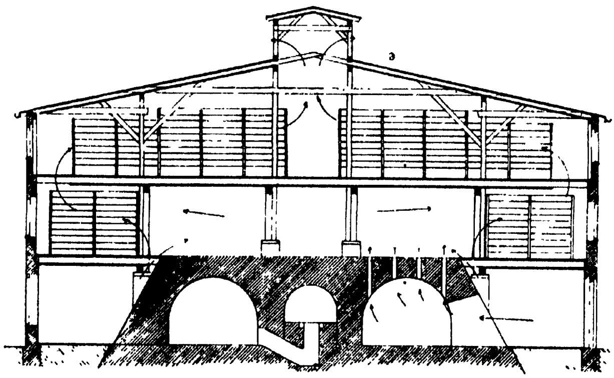


FIG. 214.—Dryer built around kiln.

increases the durability of the arches. The cost of such a roof is often regarded as an unnecessary expenditure; but it will be found that it is really economical to have a good one erected.

In Germany it is customary to surround the kiln with a dryer (fig. 214), but this arrangement is not much used in Great Britain.

If properly constructed, a kiln of the type just described should burn 1000 ordinary bricks with a maximum of $4\frac{1}{2}$ cwt. of good coal, but with certain shales less than half this will be required. The fuel consumption of some patent continuous kilns is seriously understated.

For very large kilns with twenty-eight or more chambers two independent fires and two chimneys (fig. 215) are often used and considerable economy is thereby realized.

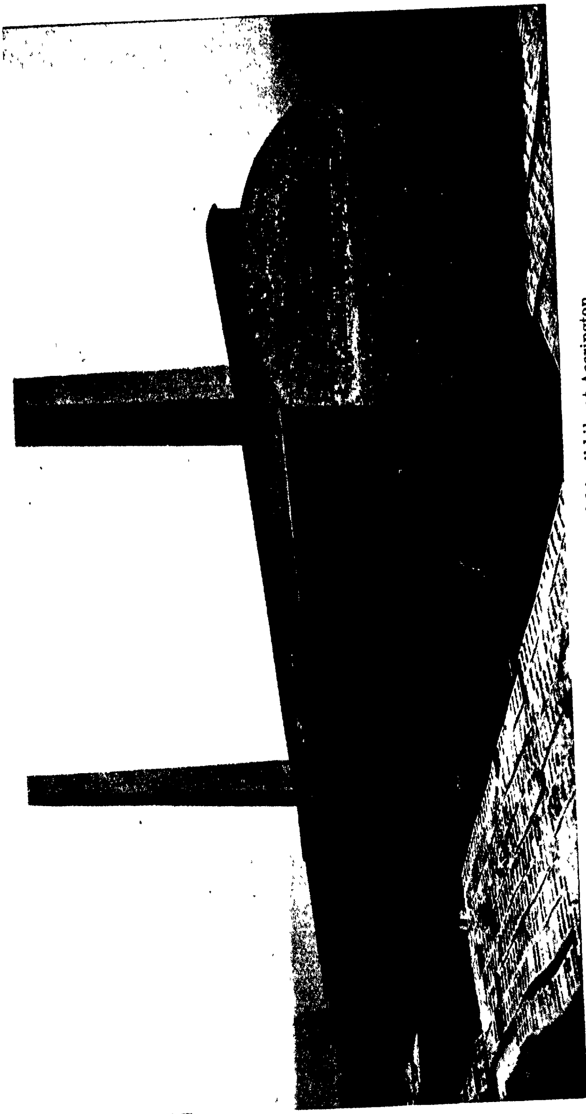


Fig. 215.—Forty-chamber "Staffordshire" kiln at Accrington.

The ordinary Hoffmann kiln is not suitable for the production of more than 60 per cent facing bricks, and for bricks containing much combustible matter; for both these kinds of bricks chamber kilns (p. 276) should be used.

The "Staffordshire" kiln (figs. 193, and 215 to 217) is eminently adapted for the production of best facing bricks, as it is a chamber kiln employing grates so as to keep the fuel out of contact with the goods, and has ample facilities for using hot air and for the removal of steam. This kiln, patented by Dean, Hetherington & Co., must not be confused with the ordinary pottery kiln used in North Staffordshire, although such mistake is natural, considering the title of the newer kiln.

The means of supplying hot and cold air to different parts of

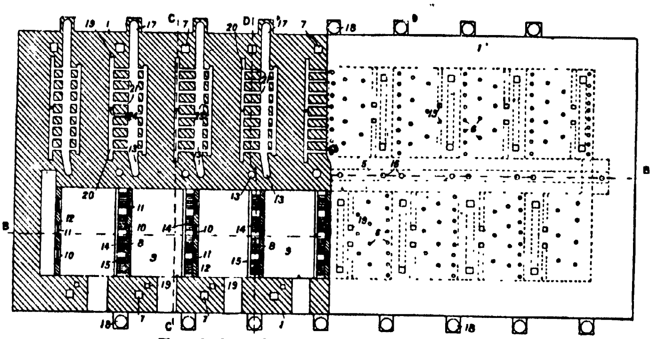


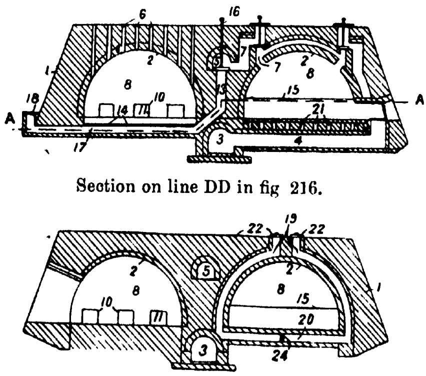
FIG. 216.—Plan of "Staffordshire" kiln.

the kiln are much more complete in it than in any kiln yet built, and, as only one face of fire is used in each chamber, this kiln is capable, under good management, of giving results equal to the best down-draught kilns with a coal consumption as small as in continuous kilns. This is brought about by the combination, in a continuous kiln, of damper-controlled passages leading from the outer air to flues under the fire-grates in the bottom of the kiln in each chamber, as shown in the illustrations (figs. 193, 216 and 217), and of similar flues leading from the hot-air flues and from the outer air in such a way that, by appropriate connexions, air of any desired temperature and in any desired volume may be admitted to any part of the kiln. The ordinary difficulties experienced in connexion with warped dampers are also to a large extent eliminated by their position and shape.

By suitably working the dampers the following results may be obtained:—

(a) By opening dampers 11 and 18 the whole or part of the hot air from the finished or cooling chambers may be admitted to the chambers containing the freshly set goods, and the steam resulting from the heating of these goods led away from the top through flues 7 and 3 to the chimney.

(b) By opening the dampers 16 of the flue 13 hot air from flue 5 may be led under the grates 14 to develop the highest possible temperature in the finishing chamber, or to distribute hot air uniformly from the hot-air flue 5 to a chamber containing green goods.



Section on line DD in fig 216.

Section on line CC in fig. 216.

FIG. 217.—Cross sections of "Staffordshire" kiln.

(c) The admission of cold air to a cooling chamber is kept under perfect control by means of dampers 18 and flues 17.

(d) The temperature of hot air entering a hot chamber from one that is cooling may be perfectly regulated by the admission of air through flues 17 and 19.

(e) The volume of air admitted through the various flues allows a nice adjustment for reducing and oxidizing atmosphere.

(f) The fire and hot gases may pass from chamber to chamber, through openings 10, whilst cold air only is admitted to the under side of the grates 14 through flues 17.

(g) Any chamber can be completely sealed by closing all the dampers, thus allowing of good annealing. This arrangement is also of great value where the goods are liable to catch fire spontaneously.

Some further particulars of the hot-air flues will be found on p. 274. It will thus be seen that in this kiln the whole of the hot air from such cooling chambers is taken direct to the main central hot-air flue, and can thus be admitted into any chamber in any part of the kiln.

The air for combustion purposes, independently of that supplied from the hot-air flue, is admitted at each end of the chamber, through dampered openings in the top; thus becoming heated on its journey to the grate. The temperature of this hot air can be further regulated by air admitted through a flue leading from the outside to directly under the fire bars.

The flues of the "Manchester" kiln are similar and are so

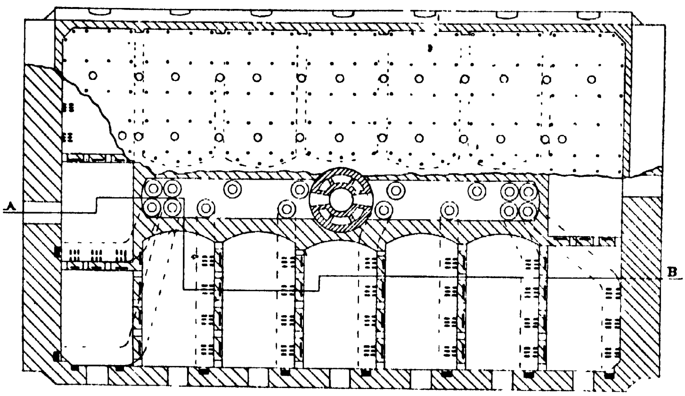


FIG. 218.—Plan of "English" kiln.

arranged that certain of them can be equally easily used for the collection of hot air, or for carrying away the steam as in the "English" kiln (figs. 194 and 218). The hot air is admitted into the chambers both at the floor level and through openings in the top.

In order to adapt them to the special characteristics of certain clays, the kilns built often differ in minor particulars from the description just given.

Most chamber kilns—the type most suited for use where facing bricks are to be made—are built with arches running transversely to the travel of the fire. This has the disadvantage of losing a certain amount of heat owing to the additional masonry, but it enables the chambers to be built of almost any size and much larger than is practicable where the arch is longitudinal,

when 18 ft. is the maximum width. The travel of the fire is also more regular in kilns with transverse arches. The London Brick Co., of Fletton, use what is known as the "English" kiln, the chief feature of which is the ingenious system of hot-air flues. These are placed in two parallel rows on top of the arches, the dampers taking the form of circular plates or lids (fig. 194), the position of which determines the direction of flow and the amount of hot air allowed to enter or escape from any chamber. The fire-gases pass through openings in the wall between the chambers (figs. 194 and 218).

This kiln is not intended to produce facing bricks of first-class colour, but for use with certain shales it is found to give great satisfaction, producing a great heat with a low consumption of fuel, the hot-air system being so arranged that very damp bricks can be set direct into the kiln.

The foregoing kilns can be used at the high temperature used in blue-brick and fire-brick making, but a special kiln for this purpose has advantages, as by using two fires the chambers can be large and the waste of heat due to small chambers can be avoided. Kilns of this type are well known on the Continent, but in this country the only one which has proved successful is that patented by S. Barnett and R. J. Hadlington, Dudley Port, Staffs, the essential features of which are (1) the use of transverse arches, (2) of two grates or fire-boxes to each chamber, and (3) the direct connecting flues between each chamber. Kilns very similar to this have been patented by G. Oakland and others, but they used one fire-trough, divided into a number of boxes or bags, in which the fuel is burned on a solid floor as in Guthrie's patent, and the connecting flues are less suited for careful regulation at the higher temperatures necessary for blue -and fire-brick burning.

The Barnett and Hadlington kiln may be regarded as a series of separate chambers with a slight space between each; this space may be used to contain the connecting flues and dampers regulating the supply of air. Owing to the desirability of large chambers the arches are built transversely. The fuel is fed exclusively from the front of the chamber as in the Belgian kiln.

The gases are not led directly through the partition walls of one chamber to another as in most continuous kilns, but pass through perforations in the floor (as in a down-draught kiln) and thence to the following chamber. The perforations in the floor are at

one side of the kiln, opposite to that at which the gases enter, but the main flue (through which pass the gases produced by the fuel on the grates within the chamber) is in the centre of the floor.

The use of this second flue at the side of the chamber farthest from the point of entry of the gases is important, as it tends to produce a better distribution of the warming gases, whilst the centre flue is to be preferred when fuel is actually being burned on the grates, because it concentrates the effect of the flames, and then distributes the gases evenly throughout the goods during the hottest part of the firing. In other words, this kiln utilizes the old idea of a grate at one end of a chamber and a flue at the other during the earlier part of the burning, but during the last forty-eight or fifty hours the heat from the two grates is concentrated by shutting off the side flue and using the centre one.

In this way, it is possible, in so far as respects the products of combustion of the fuel, to reach a very high efficiency in the transference of heated air from one chamber to another, and the successful drawing off of the steam, and its conveyance to the smoke-shaft.

Steam is removed and the goods dried with regeneratively heated air (partly from the cooling chambers) which is also utilized for supplying hot air to increase the temperature of the chambers under fire, or to assist in starting the furnaces of a chamber into which fuel has just been placed. It is conveyed through four or more large openings in the sides of the chamber containing cooling goods, through flues running underneath the chambers and up through other flues (controlled by sliding dampers) to the fire-grates of the chamber where it is to be used. It is then drawn through a special set of flues into the main leading to the chimney-stack, so that if used for goods containing much moisture the steam produced does not come in contact with any other goods, but goes direct to the chimney.

The additional air required for supporting the combustion of the fuel on the grates, or for completing the ignition of any imperfectly consumed gases, is supplied partly through the grate bars (the ash-pit being then kept open to the air) and partly by means of a small flue connecting the space above the grate-bars with the hot-air flues from the cooling chambers, and also with the open air, this open-air port being controlled by a damper about 3 ft. from the ground. In this way any desired

mixture of hot and cold air may be supplied to the contents of a chamber.

These apparently elaborate arrangements for controlling the air- and fuel-supply and the speed at which the burning takes place cannot be satisfactorily shown in one or two small illustrations, but they are, in reality, far simpler than appears at first sight, and little difficulty is found in obtaining perfectly satisfactory vitrified blue bricks or well fired fire-bricks from this kiln. The accurate burning of the fuel is essential to the production of a good colour and a proper degree of density or vitrification, and the author has found that the dampers (even after several years' constant use) work so accurately that the appearance of the flame of the hot gases in the chambers can be altered with the greatest nicety, or smothered out altogether by simply moving the appropriate dampers. This speaks highly for the soundness of the construction, and the careful placing of the dampers where they will work effectively and be least affected with the heat. These dampers are chiefly in the form of slabs of fire-clay or of the usual conical pattern. The Bock, Diesener, and Mendheim kilns, which are greatly used in Germany, are arranged on the same general principle.

Tunnel kilns are those in which the goods are placed on wagons and travel through a heated tunnel, whereas in the ordinary continuous kiln the heat travels whilst the goods remain stationary. Whilst very useful for light goods (pottery, etc.) tunnel kilns have not become popular in this country, though numerous patents have been obtained. In France, several are in satisfactory use for brickmaking.

The chief objections urged against them are the jolting of the goods on the cars and the difficulty in repairing the kilns without stopping the works, but neither of these objections is as important as many brickmakers imagine, though the former is the more troublesome with tender clays.

The great advantages of tunnel kilns are the absence of "setting"—the bricks, being loaded on to the cars at the machine, remain on them until the drying and burning is complete—the small waste of fuel due to its all being delivered at one spot instead of over a larger area as in the ordinary continuous kiln, and the economy in fuel consumption which is fully equal to, if not greater than, that of the Hoffmann kiln.

A tunnel kiln for bricks is shown in fig. 219, which represents a cross-section. The whole kiln should be at least twenty times

the length of a wagon. As the goods enter the kiln they are subjected to the heat of the waste gases, and as they pass out they give up their heat to the incoming air which, being pre-heated in this manner, effects a better combustion of the fuel.

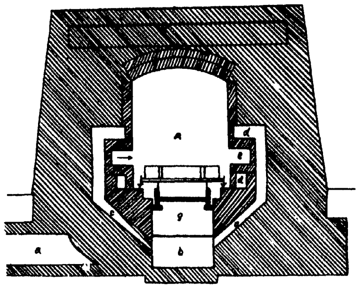


FIG. 219.—Bock's tunnel kiln.

In the Bock kiln, gas from a producer enters the central portion of the kiln, rises through the flues, and enters the burners where it meets with the pre-heated air in another chamber. The goods are placed on a single deck car, the top of which is a fire-clay slab. It is essential to use gas as a fuel, as in no other way can absolutely continuous heating without variations due to the removal of ashes be obtained.

The chief difficulty to be overcome is the effect of the intense heat on the wagon carrying the goods and on the brickwork in the hotter parts of the kiln. There is also a minor difficulty that air leaks between the sides of the wagon and the kiln, and prevents the proper heating of the goods. In spite of their advantages, tunnel kilns are scarcely likely to become popular for brick-burning.

Gas-fired continuous kilns have been known for many years, James Dunnachie having erected one at Glenboig in the year 1881, yet many attempts have been made to apply gas to kilns which have resulted in disastrous failures. Two principal reasons for these failures may be given: those attempting to use gas did not (1) know how to burn it, and (2) permit it to enter the kiln at the proper point. Subsidiary failures have been due to attempting to use cold instead of hot air for mixing with the gas, and other equally impractical ideas, the result of ignorance of the characteristics of the gas used.

It is generally thought that gas-fired kilns are difficult to manage and that they effect an enormous economy in fuel. Neither of these ideas is correct. A properly constructed gas-fired kiln is quite easy to manage—the difficulty lies in the design and not in the manipulation—and the fuel-consumption is practically the same as that of any equally well-designed coal-fired continuous kiln.

The real advantages of gas are its greater cleanliness, the better colour obtained on the goods, greater regularity in heating, and, above all, the greater finishing temperature which can be reached when gas is used. This last is of the greatest importance in fire-brick manufacture, though few British makers of refractory goods realize this fact.

The number of designs of continuous gas-fired kilns is already very large, and it must, therefore, suffice to describe only three of the best known ones. A kiln built according to Schmatolla's designs has been described already (p. 257). It is much newer than the Mendheim and the Dunnachie kilns. The Mendheim kiln is a great improvement on some of the earlier designs, and is practically a series of down-draught kilns connected to each other, the gas being burned in "bags" at one side of each chamber, and the products of combustion, after distributing themselves through the chamber, pass away through perforations in the floor to the "bag" of the next chamber or to the main flue.

In the most recent gas-fired kilns by G. Mendheim the gas enters at the four corners of each chamber and rises up the bag-walls, the product of combustion then passes out through a central opening in the floor which delivers them to the bags of the next chamber or to the main flue. This arrangement has the advantage of using a minimum number of dampers.

The Mendheim kilns appear to be rapidly increasing in popularity on the Continent.

The Dunnachie kiln has been chiefly used in connexion with fire-brick burning, though well adapted for ordinary bricks, but it has not been the policy of the inventor to encourage the erection of similar kilns in this country or in Scotland, and consequently the kiln, though well-known by name, is not familiar to more than a few privileged workers as regards its constructional details. Abroad (where the possibility of competition does not exist) a number of Dunnachie kilns have been built, and, when the original design has been closely followed, have proved quite successful and economical. It is, indeed, only to be regretted that more do not exist in this country. The Dunnachie kiln has a solid floor, thereby overcoming one of the greatest disadvantages of the Mendheim kiln, and the larger flues give a more satisfactory control as well as more rapid burning of the goods, and at the same time become much less easily choked.

The gas producer used may be of any type supplying gas at a pressure of about one-hundredth of an atmosphere (4 in. water-

column), though at Glenboig the Wilson producers are the ones actually used.

The Dunnachie kiln presents a very different appearance to the ordinary continuous kiln because of the great distance

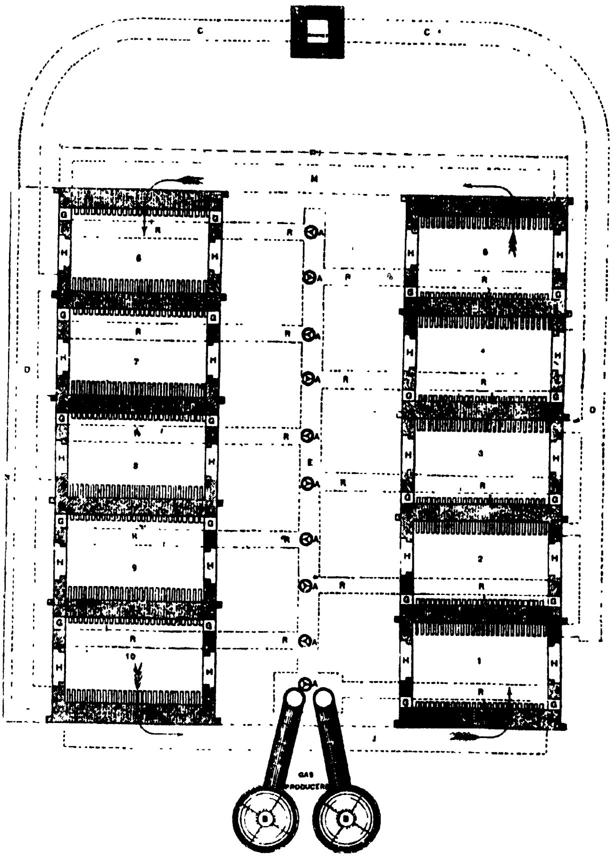


FIG. 220.—Plan of Dunnachie kiln.

between the two rows of chambers. In the ordinary coal-fired continuous kiln, with sixteen chambers, twelve are placed back to back close together, and the remaining four are placed two at each end of the others, so as to form a complete "ring". In the Dunnachie kiln (fig. 220) on the other hand, there are only ten

chambers placed in two rows of five, and with a space of 20 ft. between them, the chambers at the end of each row being connected by underground flues (J and M). In the centre of this space the gas valves are arranged, and, if roofed in, the space forms a convenient room for drying goods, being kept warm by the heat radiated from the ends of the chambers, and the heat which would otherwise be lost by this arrangement of the kilns is made use of, to the general advantage of the works. If desired, the space above the kilns may also be roofed in, and used as a making and drying floor—a custom particularly common with continuous kilns in Germany, but not so popular in Great Britain.

The chambers used at Glenboig have a capacity of about 18,000 bricks and measure 17 ft. by 10½ ft. by 10½ ft. internally, and worked at ordinary speed can produce an average output of 400,000 fire-bricks a month.

The chimney is placed at one end of the structure, the main flue leading to it being placed around the sides, as shown in fig. 220. This plan necessitates some loss of heat in the main flue, but as the gases passing through it are at a comparatively low temperature this is not considered to be of much importance, especially as the chimney-draught can be accelerated to any required extent by means of a fan. It is certainly better that the heat should be lost from the main chimney-flue rather than from the flues conveying hot gas to the kilns, which seems to be the only other alternative if the present simplicity of arrangement and accessibility of flues are to be maintained. Under such conditions a blower may be used instead of, or in addition to, the chimney- or fan-draught, but this requires care, or its use may become dangerous.

"Steaming" or "smoking" of the goods is effectually carried out by burning a small quantity of gas mixed with an abundance of cold air in the chambers to be smoked, or, if there is a sufficient supply, hot air from the cooling chambers is used. During this "steaming," openings in the arched roof of the chambers (corresponding to the "feed-holes" in the ordinary kiln of the Hoffmann type) and the ports G (fig. 220), near the floor level of the kiln, are kept open until the whole of the steam has been removed, and the goods are distinctly hot; they are then closed.

The burning then commences by admitting gas at a temperature of about 600° Fahr. from the producers through the flues R through valves A, hot air for its combustion being supplied at

the same time from the chamber which has just finished firing. It is the employment of the heat in the finished goods for heating the air required for the combustion of the gas which constitutes the principal feature of the Dunnachie kiln, and is the chief cause of its success. This kiln was, in fact, the first in this country to combine the advantages gained by the use of gas as fuel with the "regeneration" of the air used for its combustion by means of the waste heat from the burned-off chambers. This principle of heat regeneration has been recognized for nearly a hundred years, and was applied with remarkable success in 1856 to the melting of steel by the late Sir F. Siemens, but the credit of its successful application to the requirements of the clay industry must be given to Mr. James Dunnachie, who first employed it in the kiln now under consideration. For its application to *single* kilns see fig. 177.

The air is heated in a manner very similar to that now employed in most continuous kilns using coal, by drawing it through the chambers containing finished goods which are still very hot (in the case of fire-bricks of best quality the air is heated to a "blue white heat" before it comes in contact with the gaseous fuel). It is conveyed from one chamber to another by openings in the floor of the chambers leading to a flue beneath, thence through slits in the brickwork to another flue, and thence through openings in the arched roof of this latter flue into a smaller flue, from which it passes at, or slightly below, the floor level of the kiln into the next chamber by means of a series of openings, the size of which is calculated so as to supply the correct proportion of air to the gas. (Usually the capacity of the air-openings is two and a half times that of the gas.) As these air-openings extend the whole length of the chamber also, even heating is thereby effected.

The gas catches fire where it comes into contact with the air a little below the floor level, and for some distance above it, the flame rising a considerable height in the chamber in huge sheets of a clear bright colour, and practically free from smoke if the air and gas are in the correct proportions. The products of combustion then pass through the following chambers, heating the bricks in them, until the heat left in the gases is so small as to be of little value, when they are turned into the main flue leading to the chimney.

If, for any reason, a supply of air is required at a higher level than the floor of the kiln it can be supplied by opening dampers

in other flues (not shown) which are so arranged as to supply hot air from the preceding chambers or, by opening dampers at their ends, cold air can be supplied in any desired amount to the chambers. These flues are not generally required unless the firing in the burning chamber is not hot enough, or when the chamber is too hot and cold air must be supplied to prevent the bricks melting.

All these air-flues and gas-flues are controlled by dampers and valves of a simple character, and the supply of hot air or cold air and gas can be regulated with the greatest nicety to the changing conditions of the kiln.

The "round of the kiln" when burning fire-bricks is somewhat as follows:—

No. 1 Chamber—Being emptied. No. 2 Chamber—Open and cooling. No. 3 Chamber—Red hot, being cooled by air supplied through flue at its base, and carried on to No. 4 Chamber. No. 4 Chamber—White hot, being cooled by air from No. 3, which is passed on to No. 5. No. 5 Chamber—In full fire for 36 to 48 hours, being supplied with hot gas from the producers and with "white hot" air from No. 4. No. 6 Chamber—Very hot, being heated by products of combustion from No. 5. No. 7 Chamber—Heating up to red heat by gases from No. 6. No. 8 Chamber—Steaming for forty-eight hours. Filled with green bricks. No. 9 Chamber—Filling with green bricks. No. 10 Chamber—Empty, ready for filling.

The cooling of each chamber takes about seventy-two hours, though varying with the nature of the goods. It can be accelerated by the use of a blast of cold air blown into the top of the chamber during the last day of the cooling. The hot air thus obtained may be used for the kiln, any excess being employed for heating drying sheds, etc.

Though essentially designed for the highest temperatures used in fire-brick making, the Dunnachie kiln can be equally well employed with common bricks, for salt glazing (in which case a perforated floor is used so as to secure a draught inside as well as outside the goods), and for ordinary pottery purposes, though its advantages at lower temperatures are less important. For many purposes, though still capable of improvement, it is undoubtedly the greatest advance in firing that has been made since the invention of the continuous kiln by Hoffmann, as the employment of gas at high temperatures greatly lessens the repairs needed by the kilns, and by reducing the labour necessary

for supplying the fuel it enables the number of men employed for a large number of kilns to be considerably reduced, and renders their work more accurate and under better control than when a coal-fired kiln is used.

There is undoubtedly a great opening for the further application of gas to the burning of all kinds of fire-bricks, and the success which has attended the Dunnachie kiln ever since its introduction should give brickmakers an incentive to adapt their own kilns as far as possible, or to seriously consider the advisability of erecting fresh ones to be fired exclusively with gas. The reason why most firms are afraid to make the change is that they have heard or read of numerous and expensive failures to apply the gas properly to the kilns—due as already explained to the belief that it should be introduced near the top of the chambers—and are afraid to risk their own capital in a similar venture. This is bad business, because it is looking at the subject from one side only instead of regarding it from every point of view. The fact that some kiln-builders recommend a certain class of kiln is not by any means conclusive evidence that the facts which tell against their own invention are by any means fairly represented. This is where the advice of an entirely independent expert comes in, provided that one can be assured that he is independent.

The success which is being obtained in the adaptation of gas to the firing of single kilns is drawing considerable attention to the subject of gas-firing generally, and the application of this fuel to the general firing of refractory goods is only a matter of time.

The construction of gas-producers requires special knowledge, and should not be attempted by the brickmaker except under reliable supervision. The general principles involved can be learned from special books on the subject, but practical experience is essential.

The use of a gas-producer also requires a slight training, though when this is obtained the work is far easier than the ordinary stoking of kilns, and the temperature in the latter can be far more accurately and easily regulated.

Muffle kilns are used when it is necessary to keep the goods free from all contact with flame or fire-gases. In brickmaking the use of muffles is confined to some glazed bricks and to the production of red bricks from certain Staffordshire marls.

The usual form of muffle is an arched chamber placed in-

side a Newcastle or similar type of kiln, this chamber or muffle (fig. 221) being built on flues and with a space above and at each side. The front of the muffle is left open for filling, but is closed with bricks plastered over with daub before the firing is commenced. The flame and fire-gases play all round the muffle, heating it evenly and yet keeping the goods free from ash, dust, and other harmful influences.

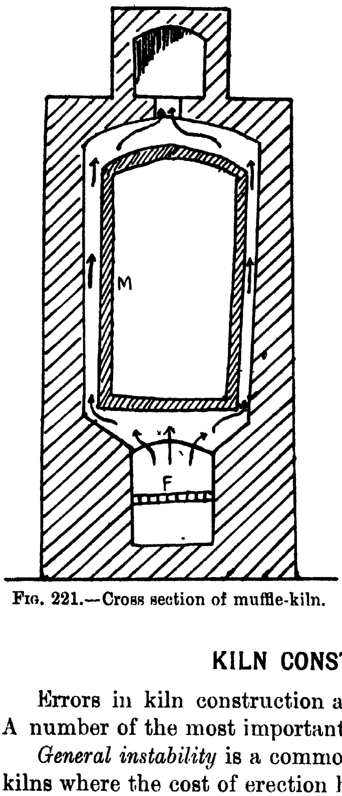


Fig. 221.—Cross section of muffle-kiln.

Providing that an even heat is obtained, the shape of the muffle is unimportant, but the design already indicated is as simple and efficient as any. The waste gases from one muffle kiln may often be used to heat another in a manner precisely similar to that used in continuous chamber kilns.

KILN CONSTRUCTION.

Errors in kiln construction are often numerous and serious. A number of the most important ones are enumerated below:—

General instability is a common feature of certain continuous kilns where the cost of erection has been reduced to below the proper limit as a result of excessive competition. This defect usually shows itself first by cracks in the outer walls and in the flues, though the former may be due to a poor foundation rather than to indifferent workmanship. It has already been pointed out that flues should not be built above the keystone of an arch if they run in the same direction as the arch itself, as the movements of the kiln during heating and cooling render this the most unstable position in the whole structure.

A form of economy often attempted is to fill large portions of the masonry with broken bricks, sand, or rubble. If well stamped down these may be satisfactory, though properly laid brickwork is far better. Occasionally, burned clay or sand is used, but it is

apt to dry, leaving hollow spaces. Slag, though better than clay, is liable to contain unburnt material and so shrink on heating.

The choice of bricks for different portions of the kilns is a matter requiring a considerable amount of attention, for it is just as foolish to use best refractory bricks where a lower grade material at half the price can be used with equal satisfaction, as it is to endeavour to save expense by using inferior bricks in those parts of the kiln which require to be most heat-resisting. By a little thought it is often possible to save considerably in the expense of erecting new kilns, or repairing or altering old ones, if this careful choice of different bricks for different positions is made.

The masonry used in the centre of most continuous kilns is a good example of a case where inferior bricks may be used, as they are heated but are not exposed to the action of the weather to any notable extent, and being usually well imbedded, only need to have sufficient strength for their work, no regard being paid to their softness or general appearance. The external

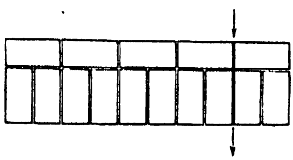


Fig. 222.—Wrong bond for bricks.

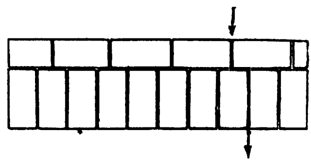


Fig. 223.—Correct bond for bricks.

work, and that which is subjected to heat, however, must be of best materials in order that it may stand the existing and probable strains and exposure without the least likelihood of failure.

Of the brickwork which comes in contact with the fire it is scarcely necessary to say that it should be constructed of the best materials, and laid with as thin joints and in as skilful a manner as possible, a small extra cost in the erection more than repaying itself in the far greater length of time the work will last as compared with badly built work of less refractory materials.

Another defective arrangement, which is more often noticed in repair work than in a newly erected kiln, is the wrong bonding of the bricks. This is carried out in such a way that instead of breaking joints with the courses above or below, the bricks are so arranged that the joints coincide as in fig. 222, whereas they should be as in fig. 223. In this latter case not only is the bond better and the masonry stronger, but the effect of cracks in the jointing is much less serious, as these cracks do not extend nearly as far when the joints are broken as when they coincide.

The *mortar* used will vary in composition according to the object of the brickwork. For the cooler portions of the work, where strength and not heat-resistance is needed, the use of ordinary lime-mortar is satisfactory, but for the more refractory portions the jointing materials should consist simply of a clay similar to that of which the bricks are made, mixed with water. Sometimes a little finely ground burned clay may be added to reduce the shrinkage of the mortar, but lime and other fluxes must be most carefully excluded where the masonry has to withstand great heat.

In the construction of a kiln *foundation* too much care cannot be taken, as dampness drawn up into the kiln because of a defective foundation is not only a source of loss of fuel, but may cause serious damage to the goods in the kiln. Bricks having a good colour and a clear "ring" cannot be economically obtained with kilns which have damp soles.

It will be easily understood that the chimney-draught causes a very slight vacuum inside the kiln, so that any air, gas, or vapour outside it, whether below or above, will tend to rush in through any pores in the soil or masonry. The heat in the soil beneath evaporates the moisture which reaches it, and the vapour inevitably finds its way into the chambers.

The effect of this is seen on the goods nearest the floor, and a marked effect also is produced on the coal consumption. Scummed and unsound bricks result, in spite of all ordinary precautions against these defects.

Brickmakers who have not studied the question carefully have no idea of the difference in the quality of the goods and the saving in fuel which results from properly draining a kiln, and the expense of installing a proper system of drainage is rapidly returned to the manufacturer who is enterprising enough to ensure that all the water in the sole of his kiln is removed in a proper manner, instead of being boiled out by heat which should be expended in firing the goods.

In erecting new kilns it is seldom that sufficient attention is paid to the *removal of foundation water*, although every kiln builder is fully aware of the necessity of properly draining the foundations of his kilns. In addition to this, most kilns are not used during the winter months, and in but few cases are proper means provided for the efficient removal of rain-water from the kiln roof; it is generally allowed to run off anywhere, and most frequently finds its way into the ground immediately around the

kiln walls. Consequently, the goods are of inferior quality, and require far more than the normal proportion of fuel, owing to the kiln and its foundations being soaked with water.

It is a good rule never to build a kiln on ground in which the subsoil water is within 6 yds. of the surface unless a special insulation system is used.

It is well known that the heat produced in firing a kiln not only rises to the upper parts of the kiln, but also sinks into the foundations, and it is not unusual to find that the first three rounds at the beginning of a new season produce goods which are inferior in quality, as it takes some time before the heat can penetrate to its normal depth of 3 to 4 yds. into the ground.

All the water present in the foundations of a kiln to a depth at which the temperature approaches 100° C. must be sooner or later evaporated and removed through the flues, fan, or chimney of the kiln. Not only so, but when a higher temperature than this is present the temperature is lowered by the evaporation which takes place, thereby causing a serious loss of heat.

It is important that every brickmaker should see that his kilns are properly drained, as, otherwise, serious trouble will result. It is equally important to see that the water from the roof of the kiln and from other buildings is not allowed to soak into the ground near the kilns, but is conveyed away out of harm's reach. If it must be allowed to enter the ground near the kilns, it must be taken to a depth of at least 4 yds. below the kiln sole, and even then it is apt to be troublesome.

A plan recommended by J. Bührer and other well-known kiln-builders consists in laying 12-in. pipes to drain the foundations of the kiln, and to turn all roof water into these, so that it may be led right away from the yard. Above these pipes (which should be about 3 yds. below the sole of the kiln), a 14 in. layer of sandstone chips should be laid, as these allow the water to drain out far better than does a layer of broken bricks or ordinary earth.

The pipes which collect the water from the roof of the kiln should be of ample size, and should be taken about a foot deeper than the drain-pipes just mentioned, as this enables the dirt and sediment to settle out and lessens the liability of the drain-pipes under the kiln to choke up with sediment.

It is often convenient to connect the drain-pipes of the kiln to a small chimney, so that the system can be kept dry by means of the continual draught of the chimney itself. Connexion may

be made to the ordinary chimney of the kiln, but a supplementary chimney is often better. The slope of the drain-pipes may be arranged to suit local conditions, but should not be less than 1 : 100. In some cases where there is much water to be removed a small well should be dug at the lowest level of the drainage system, and all the water led to this well, which can be emptied periodically with a small pump.

Another effective method of draining a kiln is to construct

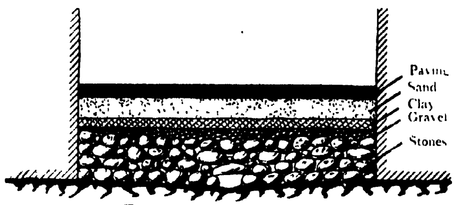


FIG. 224.—Kiln foundation.

the foundation as shown in fig. 224 in cross-section. The ground is excavated to a depth of about 3 ft. and is well rammed, with a slight fall towards the centre. A bed of large stones, 18 in. thick, is formed, with a rough kind of central canal for drawing away water. This canal must have a proper drainage outlet. On the stones a layer of gravel is placed, and then a bed of well-rammed mild clay or loam. On these two layers, which would be only 2 in. to 3 in. in thickness, is spread a good bed of sand and over this a paving of hard bricks bedded in clay.

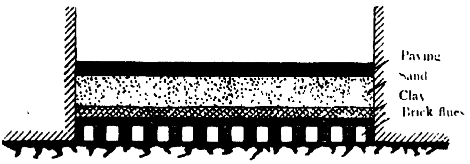
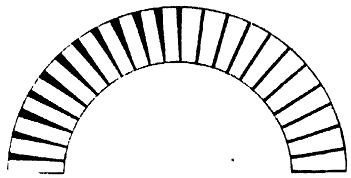


FIG. 225.—Cross section of fig. 224.

In most cases this isolation of the floor will suffice, but when water has continual access to the subsoil it is desirable to provide a means of independent liberation of the evaporated moisture which is continually produced. In this instance an effective method is to provide a complete canalization of the floor with inlets at each end of the kiln and outlets at the middle. Fig. 225 shows the cross-section of this scheme with brick flues, though 4 in. land drain-pipes may serve equally well. Over the flues are layers of loam, sand, and paving brick.

At each end of the kiln a collecting flue is formed, with a couple of inlets from the open air. At the middle, two collecting flues carry the accumulated moisture to up-cast shafts. By their draughts these shafts maintain a gentle current of air which enters at the ends and carries off the water vapour as it is formed. If the kiln chimney is sufficiently powerful, the draught may be obtained by connecting the middle flue to it, dampers

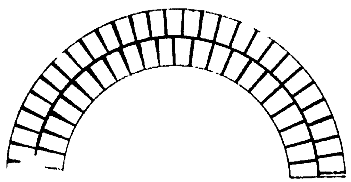


Wrong construction. Right construction.
FIG. 226.—Brickwork arch.

being provided to regulate the flow of air, but as already stated, a separate chimney is preferable.

The arches and crowns of kilns are often badly designed and constructed. There is a general tendency to use plain instead of special bricks for this purpose, with the result that a weak arch with wide joints instead of narrow ones is produced.

The difference between arches built of plain bricks and properly shaped wedges is clearly shown in figs. 226 and 227, in



Wrong construction. Right construction.
FIG. 227.—Arch of double brickwork.

both of which the left-hand side is shown constructed of plain bricks with excessively thick joints, especially at the outer ring of the arch, whilst the right-hand side shows the thin and evenly distributed jointing with wedge-shaped bricks. The difference is more noticeable in smaller arches than in large ones, and in bricks arranged as in fig. 226; but in either case the effect is the same—an excessively weak arch which must soon be repaired, and a total loss of some 80 per cent of the total expenditure as compared with the use of properly shaped wedge bricks. If the

arch is of very large diameter—over 25 ft.—the taper required is so small that it may be neglected and ordinary shaped bricks used. If, on the other hand, the kiln arch is less than 25 ft. diameter the bricks should be arranged to have a taper proportionate to the diameter of the arch.

This taper may be made by cutting the bricks before they are dry by means of a stiff knife or a specially fitted wire-cutter, or, as is preferable, they may be produced through a mouthpiece which gives them the right taper. The taper of the bricks may most conveniently be calculated as follows: Measure the inside diameter of the arch in inches and call it A. Having decided the design of the arch, measure its outside diameter, or add to the inside diameter twice the web of the arch, and call this outside diameter B. The taper of the bricks will then be B : A. That is to say, the widest and narrowest parts of the wedge-shaped arch brick will be in the proportion B : A. Instead of calculating the taper of arched bricks, it is generally better to set out a portion of the arch to full scale on a convenient board or floor, and to take the measurements direct from this, as the bricks can thus be tried before many are made, and small errors (if any) altered.

For most purposes the use of hollow bricks is better than plain, solid ones for kiln arches, as the former are not nearly so heavy, and yet are of practically equal strength.

The strength of the arches is a matter often needing special care, for it must be remembered that the masonry must not only be sufficiently refractory to withstand high temperatures, but it must also be possessed of such resisting power that it can bear the strains set up by the continual contraction and expansion. Flattened arches are, therefore, to be avoided, as are also those with a very pronounced point. In almost every case the true semi-circle is the best form of arch.

In the case of a continuous kiln it is usually wise to have the feed-holes through which the coal is supplied to the kiln made of blocks of fire-clay or at any rate of the most refractory clay easily obtainable. The number of these blocks in an arch varies with the number of feed-holes, and in the accompanying illustration (fig. 228) three blocks are used.

In constructing arches of bricks and blocks, care is needed to get the shapes of the latter correct so that they fit well to the bricks, as, otherwise, there is a serious danger of collapse after the kiln has been in use for some time. In setting out such an

arch the most important measurements are indicated by the dotted lines in figs. 228 and 229, in both of which r is the radius of the semi-circle composing the arch. Where these blocks can be purchased ready-made the speed of building is greatly

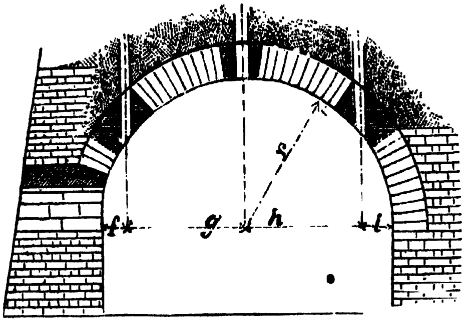


FIG. 228.—Section of chamber of continuous kiln.

increased, but even when they have to be made specially they soon repay their cost in the additional strength, security, and freedom from slip which they give to the arches in which they are used. The wicket arches may be constructed in a similar

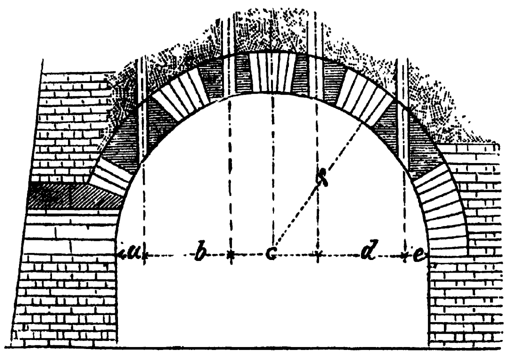


FIG. 229.—Section of chamber of continuous kiln.

manner, but where special blocks can be made, they improve the appearance of the kiln. Such blocks are now supplied ready for use by several German fire-clay manufacturers, the one shown in fig. 230 being popular on account of its neatness and strength. Like the other arches it is of a semi-circular or Roman type. The distance r should never be less than 20 in. so

as to allow ample room for the men to enter the kiln without scraping the bricks. Fire-clay blocks used in arch construction should be of open material, so as to respond readily to sudden changes in temperature without damage. They must be fired in such a way that they do not warp, and if at all twisted must be carefully dressed before use.

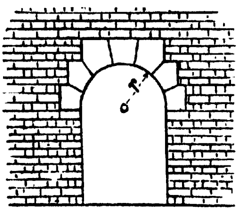


FIG. 230.—Wicket arch.

"Drop arches" are often built in continuous kilns to prevent the air travelling along the top of the inside of the kiln at too rapid a rate. They are primarily intended to act as baffles and are generally desirable though not indispensable. Their strength need not be great, though they act as supports for the proper arch. Their shape is clearly shown in fig. 231.

In single round kilns the whole roof or crown is dome-shaped, the curvature of the crown usually being part of a true circle

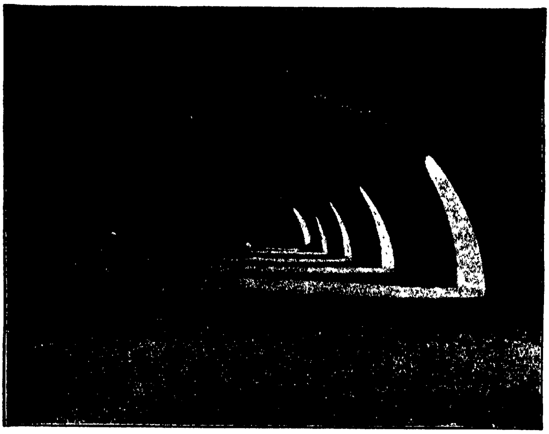


FIG. 231.—Interior of Osman kiln.

though not a complete semi-circle. This form of crown is much stronger and in every way preferable to one which is either more pointed or flatter.

The *fire-boxes* and bags of a kiln need careful design and construction if the heat is to be economically produced and evenly

distributed. Usually the fire-boxes are too shallow and allow too much air to enter above the fuel. The "box" or hopper pattern where a considerable depth of fuel is present and forms its own seal, is usually the best for single kilns. In continuous kilns the depth of fuel on the grate, or in the trough, is of less importance, and in those of the original Hoffmann type no permanent fire-boxes are used.

The *feed-holes* in the top of the kiln must be kept covered with air-tight caps or bells. In many cases the amount of air which leaks in through the caps is sufficient to spoil the draught and prevent satisfactory firing. As the top of the kiln is hot, a liquid seal cannot be employed, but some form of sand-seal should be used. The common practice of a simple bell fitting on to a raised rim is far from satisfactory. The use of a conical lid fitting into a ring (fig. 232) is but little better, as, whilst air-tight when new, the effect of repeated heating and cooling makes the

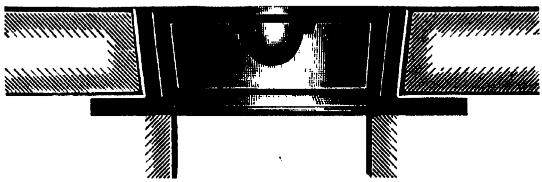


FIG. 232.—Conical cap in feed-hole.

metal twist and fit badly. A simple and durable, but at the same time air-tight, cap is greatly to be desired, and there is scope for ingenuity in this direction.

The position of the feed-holes may be seen in figs. 228, 229.

The *flues* of most kinds of kilns, but particularly those of the continuous type, need unusual care in regard to their arrangement and construction.

A common error with some kiln builders consists in constructing flues, the sizes of which have no relation to each other or to the capacity of the kiln; their dimensions being determined largely by guess-work. In a kiln with simple flues this may often prove satisfactory, particularly if all the flues are larger than is really necessary, but in many cases defective draught is produced and disappointment is caused when a 15-in. square flue cannot discharge its contents completely into a 12-in. flue some distance away, with probably a couple of bends between them. It is frequently desirable to connect smaller flues to larger ones

so as to vary the speed of the gases travelling through them, but this should only be done when the designer has a definite object in mind and is fully aware of the consequences. Such little troubles as are caused by discharging flue gases through opposite openings in the same flue without any midfeather are frequently met with, and are a continual source of mystery until some one finds out what is really the matter. Fortunately, they can usually be put right when found.

On the Continent, small flues are frequently made of sanitary pipes carefully bedded, it being considered that they are tighter than the brickwork flues almost exclusively employed in Great Britain.

Flues are often made too small and inaccessible as well as being placed in positions which are undesirable from the point of stability. Their walls are often too thin and the connexion with other flues badly made. The connecting flue of a continuous kiln should be sufficiently roomy for an ordinary sized man to get inside it easily for cleaning purposes, and should be provided with so many openings that, no matter which part of the kiln is under fire, the flues may be entered in the cooler parts direct from one of these manholes. The covers for these manholes must, of course, be kept air-tight, usually by means of sand and often by a second cover of wood or iron. Sometimes defective draught is caused less by the flues than by unsuitable dampers.

All dampers should fit tightly when closed, a "sand-seal" (similar to a water-seal) being used if necessary. They should usually be designed and made specially, as home-made dampers are often unreliable. In continuous kilns the tightness of the dampers is of very great importance.

Chimneys are often too slightly built, and so lose heat and draught-producing power. Lined chimneys have a great advantage in this respect.

The attempt to save money by building a chimney which is only just large enough for the work is really a false economy, as sooner or later it will result in the gases being turned into the chimney at too high a temperature, and consequently any saving on the original cost of the stack will be more than counterbalanced by the unnecessary high expenditure of fuel in firing the kiln. The chimney must be regarded as a "capital" investment, and the saving effected by its use must be reckoned as legitimate interest on the capital spent. If a short chimney is erected, the fuel wasted by turning hot gases into the chimney

will represent an annual expenditure corresponding to possibly 25 per cent interest on the additional amount of money originally required to have made the chimney of the right size. Not only so, but with ample chimney capacity (in other words with ample draught) it is possible to "smoke" the bricks far more effectively, and so not only increase the output of the kiln, but to turn out a better class of goods, and, consequently, to produce a larger income for the same amount of expenditure.

For this reason, it is usually desirable to substitute a fan for a chimney in cases where the capital available is not sufficient to build a chimney of ample size. The relative advantages of fans and chimneys are described on page 288.

It has already been pointed out that a *roof* is essential on all continuous kilns, and it is desirable to have one erected over single kilns if the best or most economical results are expected from the firing. The reason is that all water which is driven off the top of the kiln by evaporation represents a definite waste of fuel which could be saved by the erection of a roof or shed over the kiln. When no roof is provided, the crown or arches of the kiln begin to sag on account of the rain soaking into the brickwork, instead of being carried off by a roof; the fuel is wasted because the kiln has to be dried after each shower, and because the fuel stored around or on top of the kiln is, in winter, in a soaked condition. The fireman, too, does his work in a less satisfactory manner, because he has to be exposed to the cold and rain; whereas in a properly constructed kiln both he and the fuel, as well as the brickwork itself, would be covered by a roof which would effectually protect them all.

It is curious how many firms will spend £1000 or so in building a kiln, and yet will not lay down the extra sum required to keep their kiln in good condition by erecting a cover over it.

In *selecting a kiln* for a given brickyard it must be remembered that the pivot upon which the success or failure of a clay-works turns is frequently due, not to the clay but to the kilns employed. The proportion of the total interest on capital chargeable to the kilns is very high in many yards, and thus, the choice of a kiln is of the greatest importance. Besides, the kiln is the final machine through which the bricks must pass, and, consequently, if it works unsatisfactorily, all the labour expended in making, drying, etc., is lost, as well as the loss directly attributable to the kiln itself.

Many brickmakers think that because a certain kiln is suitable for a similar clay to their own, it is equally fitted for burning their own clay, without any modification or adaptation, and far too many continue to make wares of inferior quality when, with a little alteration either in structure, setting, or firing, they might produce a large percentage of well-coloured, soundly ringing bricks.

The most economical kiln is the continuous kiln of the Hoffmann type and its many modifications for special clays and classes of goods, yet such kilns have, unfortunately, a decided limit below which they are not economical, and firms with an output of only 500,000 bricks or less per year will be well advised not to invest in a continuous kiln, statements by kiln builders to the contrary notwithstanding. There are several reasons for this, but one of the most important is that it does not pay to build a kiln which is too large and must be worked far below its normal capacity.

A further disadvantage of installing a continuous kiln for small outputs, or for widely varying outputs, is the temptation it offers to the foreman and works manager to make too large an output for the demand. Some brickmakers imagine that it makes no difference whether one makes a small quantity at a certain profit or double the quantity at half the profit. This is a false argument, for it does not include the wear and tear on plant and kiln due to more rapid working; and whilst the machinery may be easily repaired at a small cost, what about the kiln?

On the other hand, it is not wise to select a kiln which is likely to be too small, though this is far less an evil than too large a kiln. "Large kilns bring great anxieties, whilst small kilns bring small pleasures." If times are bad a small kiln means less loss, but on the other hand, a small kiln is very annoying in days of sudden good trade, in which there is no time to erect additional kiln room before the boom has passed. On this account as fair an average as possible should be used as the basis on which to determine the size of kiln to be erected, so that the annoyance of unavoidable loss on the one hand and unattainable profit on the other shall be avoided.

A clamp kiln is rapidly becoming obsolete in many districts on account of the impossibility of obtaining many facing bricks from it, some of the bricks being under-fired whilst others are so badly scorched that in some cases they are half melted. It is

impossible to get all the bricks fired at the same temperature, but in Kent, etc., architects insist on clamp-bricks.

Clamp kilns are frequently employed in order to obtain bricks for the erection of a kiln in a newly started work, but, unless the cartage is likely to prove most unusually heavy, it is scarcely any cheaper to make and burn the bricks on the site than it is to purchase them from a neighbouring yard, for clamp kilns are often wasteful in fuel, and the brick trade for several years has been in such a state that almost any yard will sell bricks at but little over actual cost, and be satisfied that they have made a good bargain!

Intermittent kilns certainly cost less to erect than a continuous kiln, but not when they are of the same capacity as the latter. The main advantage offered by single kilns is that a man can put up two intermittent or single kilns, whereas it does not pay to erect less than six chambers in a continuous or semi-continuous kiln, as so small a number does not give the user the full benefit of the heat in the waste gases. Consequently, when only a small output is required, a few single kilns are often preferred.

If it is expected to increase the output rapidly to above 1,000,000 per annum, it is better to build part of a continuous kiln, and to work it on the semi-continuous principle rather than to build separate kilns which will be thrown out of use when a larger one is built. For certain classes of work, however, it is still necessary to use single kilns.

Probably the best form of brick kiln is a partially built continuous kiln, as this, whilst complete in itself, is always available for extension whenever the increasing trade of the district demands a larger kiln. When part of a continuous kiln is built it is not so economical in fuel as the whole kiln, but it is not so wasteful as are intermittent kilns of the same capacity. At the same time each enlargement of the kiln increases its economy of working, and there is no setting aside of kilns which are not wanted because they have been replaced by a continuous kiln, as is the case in many yards at the present time.

In the erection of such a partial kiln it is necessary to consider carefully the character of the clay, as when a delicate clay requiring very slow and gentle warming is to be fired, a much more complete kiln should be built than if a small output of a readily fired clay is required.

The size of the kiln must, as already noted, be equal to the

average output, or a trifle larger, as it is better to miss a little trade in the best years than to be saddled with too large a kiln during bad seasons. The question whether it is better to have two moderate sized continuous kilns or one single one of equal capacity is one which admits of much discussion, though the actual loss of working a large kiln partially is less than working a small kiln fully and keeping another of equal size quite idle except for occasional use. Owing to the heat to which they are subjected, kilns do not resist the action of the weather well when out of use for a long time, and it is better to have one rather than two continuous kilns, but this should not be much larger than the average output of the works for a period extending over several years, if the best results are to be obtained.

The length of a continuous kiln should be sufficient to fully utilize the "waste" heat from the fuel. There is a great tendency to build kilns which are too short, with the result that the heat which should be obtained from the cooling goods and from the fire-gases is lost, instead of being utilized for drying and heating the freshly placed goods.

Where a small output is required the kiln should have a narrow tunnel, the width being increased with large outputs, instead of the usual method—of retaining the width constant and reducing the length—being adopted.

The width of the tunnel of a continuous kiln is sometimes the subject of strange criticisms. It is frequently stated that tunnels not more than 8 ft. 6 in. or 9 ft. are best and that wider ones are detrimental to the quality of the goods. As a matter of fact, the width of the tunnel can be made 18 ft. without any disadvantages arising, provided the kiln be properly built and fired, and with transverse arches still wider chambers can be satisfactorily employed where the output justifies their use.

Where very large outputs are required, it will often be found best to build continuous kilns of a shape similar to one of the plans shown in fig. 233. These are known as "Shank Kilns," and owing to their special shape several fires can be kept going in each with a minimum of labour, and the cost of erection is less than that of several continuous kilns of equal total capacity. A considerable number—over 200—of these shank kilns are in existence on the Continent with an annual output varying from 5,000,000 to 50,000,000 each.

A continuous kiln can sometimes be enlarged by adopting the "Shank" principle just described; such an alteration to an

old circular Hoffmann is shown in fig. 234, which is reproduced from the "British Clayworker".

In enlarging a kiln in this way it may be necessary to supplement the chimney-draught by the aid of a fan.

A great advantage to be gained from the enlarging of a kiln

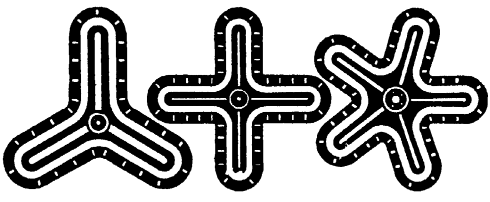


FIG. 233.—Plans of shank kilns.

in this manner is found in the instance of bricks or tiles which need very careful warming or prolonged heating as, with so long a fire-canal as is thus produced, it is possible to burn the most delicate clays with ease. In some cases it is even possible to dispense with a dryer and to remove the moisture by a some-

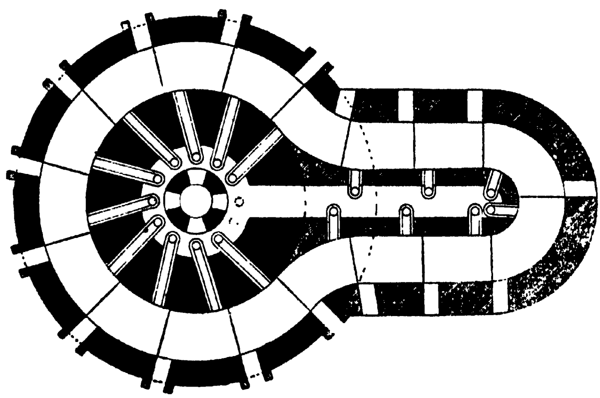


FIG. 234.—Plan of enlarged Hoffmann kiln.

what longer steaming in a manner impossible with the ordinary twelve-chamber Hoffmann kiln. It was, in fact, the necessity of treating a new clay found in the course of working an old and almost worked out pit that first compelled a certain brickmaker to find a method of enlarging his old kiln, and by doing it as

shown in fig. 234, he was able to work an unusually delicate clay with perfect satisfaction.

SETTING AND BURNING.

Bricks must be placed (or "set") in kilns in certain patterns, according to the nature of the kiln and the kind of bricks to be produced.

Thus, in an up-draught kiln, the bricks must be arranged differently to those fired in a down-draught or continuous kiln. Again, where glaze or colour is of great importance, it is necessary to so place the bricks that the "face" is protected, whilst for commoner bricks no such protective arrangement is necessary. Many firms fail to obtain the best results simply because they do not set the bricks to the greatest advantage in the kilns, using a down-draught arrangement where one suitable for horizontal draught is required and vice versa.

Unless dried by the Scott system, or set direct in continuous kilns after being made by the stiff-plastic, the semi-dry or dust processes, bricks should be dry when they enter the kilns. The method or process by which the bricks have been made is therefore of little or no importance as far as the setting in the kiln is concerned. A wise brickmaker will, however, insist on the dampest bricks (if there are any) being placed uppermost in the kiln so that the moisture in them may escape more readily and with less liability to damage other bricks. Methods of setting may be divided into four classes: (1) for up-draught; (2) for down-draught; (3) for horizontal-draught, and (4) where special protection (as in glazed bricks) is needed.

In an *up-draught kiln* the heat enters, nominally, below the goods and rises through them, though in practice it chiefly enters at the sides. The bricks should be set about $\frac{3}{4}$ in. apart, with their longest side parallel to the direction in which the horizontal portion of the fire travels—usually from the fire-box to the centre of the kiln. Less frequently, the bricks are arranged upright, each row breaking joint with the row below it. Usually, but little difference is made between the setting of up- and down-draught kilns, and providing the conditions already mentioned are maintained, the methods described for down-draught kilns may usually be followed. The main points to remember are that the heat must be able to circulate freely and evenly among the bricks, and the bricks must be so arranged as not to slip

out of place. This latter requirement usually necessitates their being crossed by bricks running at right angles every few courses.

In a *down-draught kiln* the heat rises behind a flash-wall or bag and descends upon the bricks in a downward and sloping direction. It distributes itself amongst the goods and passes out through one or more openings in the centre of the kiln.

If, as is often the case, only one exit is provided, the bricks must be set somewhat closer near the centre of the kiln and more open (about $1\frac{1}{2}$ in. apart) for the lowest four rows nearer the sides, so that the outer parts of the floor may be fully heated; or the flash- or bag-wall may be perforated near the floor so as to allow some heat to pass direct towards the centre flue. When a perforated kiln-sole is used these precautions are less necessary.

In a down-draught kiln the bricks are usually placed "five on two" (fig. 235), as this forms a convenient and easily remembered arrangement and one of ample strength. With thicker bricks the nearest to this must be used, the bricks being set about $\frac{3}{4}$ in. apart. Where the bricks are sufficiently stable another row of bricks may be set on the five headers, and sometimes a second row of stretchers is used.

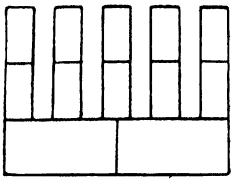


FIG. 235.—Bricks set "double five on two".

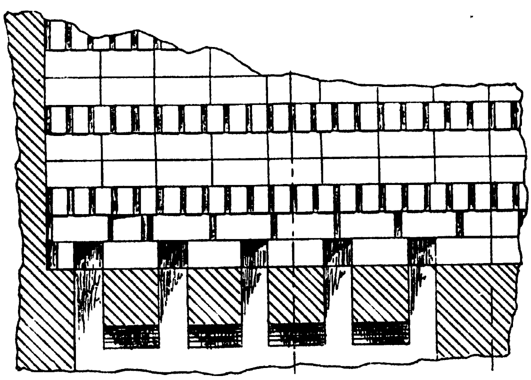


FIG. 236.—Section of lower part of kiln showing perforations (Brown).

The bottom two courses must be arranged so as to leave any perforations in the kiln sole fully open (fig. 236), after this the

setting may proceed regularly until the kiln is filled to the level of the top of the bag- or flash-wall. It is unwise to fill it higher, as the fire-gases require a considerable amount of space for their proper combustion and distribution, and this is not provided when the kiln is too full. Down-draught kilns differ from up-draught ones in this respect.

Some bricks—particularly those burning buff or white—are better set flat in "walls" or "blades" 9 in. wide, care being taken to let the bricks break joint, and being about $\frac{3}{4}$ in. apart, the "faces" never being in contact as is the case with red facing bricks. Some white or buff bricks (including most fire-bricks) are best set in this way, the ends facing the fire.

In setting red facing bricks in a down-draught kiln special precautions have to be taken, there being a great risk of producing a grey stain on the bricks, and many thousands of such bricks are spoiled annually by an improper method of setting. To obtain a first-class red facing brick the kiln-floor must be level and the arrangement of bottom flues already given is usually satisfactory, though some bricks are better if the set-off or bottom portion has 9-in. flues, four bricks deep, and a double span over, and a tier of bricks to stretch across the top, breaking the joints of each flue and thus making the bottom very strong to stand the heat. Care should be taken not to set the bricks too close in the bottom. From the set-off of the kiln, bricks made from a semi-dry machine may be set four bricks one on top of the other, with a double row of stretchers above; this alternation of four headers and two stretchers being repeated until the kiln is filled. Wire-cuts and sand-stocks will only stand three headers high. Sand-stocks do not stain as much as semi-dry bricks, on account of the sand on the face.

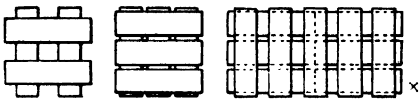
Bricks should, usually, be set from side to side in the kiln in rows or "bolts," and care should be taken by the setter, after the first double bolt is finished, to keep the heads, or ends, of the bricks in the remaining bolts in a straight line with and tight to one another, so that one may look right through the chamber from the first bolt to the last. This gives the steam and fire-gases a straight line and a free course without any chance of staining the faces of the bricks.

In round, down-draught kilns with a centre flue, it is usual to lay bricks radially from end to end, and so converge the spaces between the bottom two or three courses towards the centre. These two or three courses are laid exactly one over

the other, stretcher faces in contact. On this "foot" the usual setting is adopted of five bricks side by side over two bricks end to end. If the bricks are more than $2\frac{3}{4}$ in. thick the five bricks will be correspondingly less in number. This regular setting above the foot should be started in a way to suit the tying-in of the radially placed bricks of the foot.

Other arrangements for setting bricks in a down-draught kiln are known as "2 on 2," "3 on 3," and "5 on 6" respectively. The first is used where very open setting is necessary; the last is suitable where the bricks are finished at a low heat and where an unusual amount of support is needed (fig. 237).

In a *horizontal draught* or *continuous kiln* the setting of the bricks is slightly different. As the draught is not required to rise, it is possible to lay the stretcher bricks closer together than in an up-draught or down-draught kiln, and any vertical spaces



a *b* *c*

FIG. 237.—Brick arrangements.
(*a*) "2 on 2."
(*b*) "3 on 3."
(*c*) "5 on 6."

between the rows, "blades" or bolts are of far less importance in a horizontal-draught kiln.

In setting bricks in a continuous kiln it must be remembered that they will be subjected to a horizontal draught which will have a natural tendency to travel along the roof between the top of the setting and the arch. This upward tendency must be prevented as much as possible, and this is accomplished by setting the bricks close to the arch, and when the wares are not of a very combustible nature it is generally advantageous to pitch, or set closely together, the top two or three courses, thus diminishing the number of top-draughts or channels.

To keep the cold air from travelling too quickly between the arch and the brick in the burnt section, drop arches are generally built in each chamber (this applies only to the Hoffmann type of kiln). These drop arches, as a rule, answer their purpose well, though excellent results may be obtained by putting the top brick of the setting into the feed-hole; if any difficulty

is found in stopping the hole, soft clay should be used, the real object being to prevent the fine coal from dropping to the bottom of the kiln. This will give a very useful fire on the top of the brick, which will heat the air if there is too free a passage along the top of the brick, due to their settling. The usual arrangement is to set a row of bricks on edge $\frac{3}{4}$ in. apart in the direction in which the fire travels, and on these another row. A third or even a fourth row may be added if desired, though it makes the setting less stable. Across these bricks a single row is set at

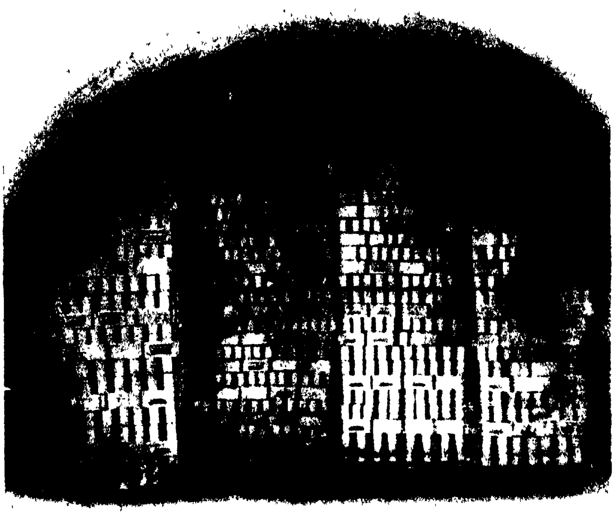


FIG. 238.—View of bricks in continuous kiln.

right angles, and on this another two rows of headers. This alternation of one row of headers and two of stretchers is continued until the kiln is filled almost to the top (fig. 238).

Where a somewhat greater flue-space is required, three bricks may be arranged on each other as shown in fig. 239. By setting the bricks in pairs greater stability is obtained than if the flue-space is left between each set of upright bricks. There should be ample draught space in the lower portion of the setting, particularly in the trace-holes. These trace-holes are in the same direction as the draught during the whole period of burning, as

they may become choked with coal or ash, which would merely retard the progress of the fire throughout the kiln.

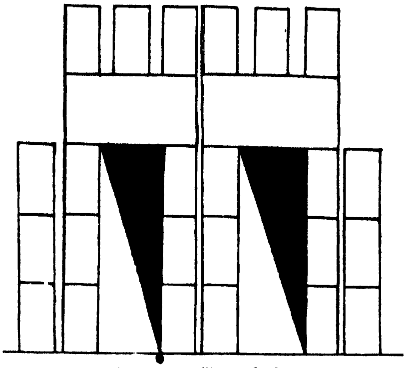


FIG. 239.—Trace-holes.

An important point to be taken care of is that of determining the number of sections of chambers to be set, taken on and treated as one chamber in the Hoffmann kiln. The writer has known difficulties to arise from too large a number of chambers being coupled together in this way. Two chambers are quite sufficient to be coupled together and is as large a section as is consistent with good management. Each section should have a papered end unless permanent partition walls exist.

In a continuous or other horizontal draught-kiln there is no need to stop short of filling completely to the top of the arch, as the combustion of the gases takes place elsewhere and not, as in a down-draught kiln, above the goods.

With kilns with a horizontal-draught the combustion space, or "free" space, must be at right angles to the draught; in a Newcastle kiln it is immediately behind the fire-boxes (a space of 3 ft. or so in width being left on purpose) and in some continuous kilns it is immediately above and to one side of the grates, fire-troughs, or bags. Hence in continuous chamber kilns the goods nearest to the fuel should not be set vertically but with a distinct slope in the direction of the draught.

When the fuel is fed amongst the bricks in a continuous kiln (as in the original Hoffmann kiln) the same general arrangement of setting is used, but beneath each of the pot-holes in the roof a vertical flue is left in which the fuel can burn. One pattern of such a "flue" is shown in fig. 240, certain bricks being made to project in such a manner as to form a series of ledges on which the fuel can rest and burn, only a very small portion falling direct to the bottom of the kiln.

For a beginner, the best way to construct one of these flues is to fix a plank about 1 in. thick and a little narrower than

the pot-hole in the arch of the kiln, vertically below (and through) the hole, and to set the bricks alternately close to and away from this lath on all sides so as to form the vertical space shown in fig. 240; the enlarged space at the bottom of the shaft serves to contain the ashes from the fuel, and to enable the burner to estimate the temperature of the lower part of the kiln.

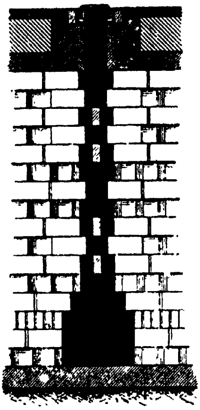


FIG. 240.—Fuel shaft in Hoffmann kiln.

Fire-shafts of other shapes are preferred by some burners—much depending on the fuel used—and in some parts of the Midlands they are built by setting bricks in pairs as headers and stretchers alternately (fig. 237*a*). One of the great disadvantages of the use of such fire-columns is the liability to errors in setting which they cause, and such errors are often discovered only when too late to be repaired. To avoid them it is essential that the changes in the setting in various parts of the kiln should be reduced to a minimum, and, however desirable from the burner's standpoint, the practice of setting the bricks closer to each other as the arch is approached, and other methods requiring special skill on the part of the setters, cannot be considered as ideal. For this reason the author has frequently used with success a method which consists in leaving a space between the blades or walls, in which "trough," bricks are set in rows on their edges as shown in the centre and sides of figs. 241 and 242. This arrangement provides ample ties for the bricks, and requires no laths or other guides for the setters to enable them to keep the flues properly in line, as the joints of the bricks show where the next layer of bricks is to be placed. The construction of the fire columns is also simplified, as will be seen from the illustrations, as a single space is left throughout the whole width of the chamber. This space is $2\frac{1}{2}$ to 3 in. wide, and on the bricks which partially bridge over the space, some of the fuel will be retained in the upper part of the kiln.

The aperture in each chamber which leads to the main flue is made by leaving a space about 4 in. wide, and extending the whole breadth of the kiln. The fourth row of bricks from the bottom is laid close, so as to form the top of this shallow flue

which leads the gases direct to the main flue. Various forms of this "trough" arrangement are much used in France (*four à tranches*) and in Germany (*Heizwände*).

If the bricks are dried by fires placed at the wicket, a series of flues is made to carry the heat from these fires as far into the chamber as possible, as otherwise the direction of the heat will be from the wicket to the nearest exit and a large portion of the chamber will always be left cold.

To obtain facing bricks of good colour the setting must usually be similar to that in down-draught kilns, i.e. two faces are placed together before they are tied crosswise by two more, and so continued up to the required height. The flues or passages are, however, arranged in the same way as when common bricks are burned.

The most recent method of setting bricks is one exploited by the American Clay Machinery Co. So far, it has only been used in the United States for setting stiff plastic and semi-dry bricks direct into the kiln. A travelling crane carries a hod of 120 bricks from the machine to the place where they are to be set in the kiln, and deposits the bricks ready for burning. The arrangement of the bricks on the hod determines the setting, the bricks being built up in "units" which are stacked on each other. In the very large open rectangular kilns (*scoves*) used in the States, and to a smaller extent in archless continuous kilns, this method appears to possess advantages over hand-setting for common bricks, but it can, obviously, only be used in those cases where an overhead rail or crane can deliver the hods to each part of the kiln.

After a "chamber" has been set it must be separated from the remainder of the kiln by means of dampers. Where no permanent cross-walls are used it is convenient to fasten sheets of paper right across the bricks, smearing the edges of the paper with clay-paste to make the partition air-tight. The special characteristics required in paper used for this purpose are described on page 277. The paper must be joined with good paste if single sheets of sufficient size cannot be obtained, as leaks are very objectionable and waste fuel.

When permanent walls are erected, the paper need only be pasted over the trace-holes, though permanent dampers of iron and fire-clay are often used instead. Three chief forms of damper-leakages are possible and must be considered separately :—

(*a*) The damper nearest the kiln fire may leak, and consequently the hot air as it enters will be more or less completely drawn through it and away to the chimney from the flue in the chamber nearer the fire, instead of its being drawn around the goods to be smoked, and after warming them, passing away through the main flue.

(*b*) The damper nearest the empty chamber may leak and the one at the other end of the chamber being smoked may be tight, with the result that cold air will be drawn into the chamber to be smoked through the nearest open wicket, and will not only diminish the amount of hot air drawn around the goods to be smoked, but will itself take up some of the heat to no purpose, and may tend to crack the goods by placing them in contact with cold air.

(*c*) Both dampers may leak at the same time. In such a case both the defects previously mentioned will be increased by their mutual action on each other, and a particularly unsatisfactory smoking will be produced.

The chief precautions to be taken to prevent these troubles depend on the causes of leakage, and are as follows: (1) Leakage due to bad workmanship in pasting on the damper, or to the use of too thin a clay slip, or to a slip made of too fat a clay. This may be cured by improved workmanship, by seeing that the slip is a thinnish paste and not a mere liquid, and of the right composition. In many cases also, the leakage is due to insufficient margin round the opening. As already explained, this should be ample in order to secure a tight joint.

(2) Defects in the walling of which the partition is made, and which suggest partial rebuilding as the most satisfactory cure. The use of a poor paper would act similarly, and either a more waterproof paper must be purchased or it should be pasted over with clay slip.

(3) Insufficient draught in the chamber being smoked, thereby causing a deposit of condensed steam on the paper partition, which soddens it and causes it to collapse, or which may prevent its burning sufficiently soon. The draught in the smoking chamber, should, whenever the goods will stand it, be as strong as that for the remainder of the kiln, and like it should be measured with continuous reading gauge. Careless regulation of the draught will sometimes put such a sudden strain on the paper partition as to rupture it, so that the burner should remove his flue-dampers with sufficient slowness.

(4) The stove may be too near the damper, and sparks from it may set the latter on fire, thereby producing what is to all intents and purposes a serious leak. A simple bending of the pipe so that no sparks can possibly get on the paper will prevent this disaster.

Special Goods such as hollow blocks, moulded bricks, etc., which must be specially protected in the kiln, are usually burned in small chambers built for the purpose inside the kiln; as long as these chambers are not large no difficulty need be experienced, but when considerable space is required special arrangements must be made.

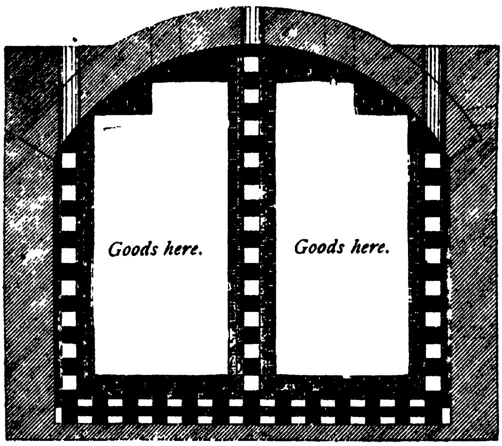


Fig. 241.—Cross section of temporary muffles.

Where the demand for goods which have to be protected in the kiln is sufficiently great a muffle kiln should be used, but when this is not required the arrangement of part of a continuous kiln, as suggested by F. Hoffmann (figs. 241 and 242), will often be found satisfactory. Fig. 241 shows a hollow chamber on each side of a special flue, two such chambers and the necessary flues extending the whole width of the tunnel or chambers. The bottom flues are not built with solid walls but in chequer work, the space between the ends of each brick being $2\frac{1}{4}$ to $2\frac{1}{2}$ in. The side and centre flues are arranged to act as fire-columns as well as flues, their construction being shown in cross-section in fig. 241 and in plan in fig. 242. Full protection of the goods is secured

by two rows of bricks set close and smeared with daub, which form the special chamber. The special goods having been set in the chambers provided, a front wall of bricks set close is erected and daubed. It is, however, wisest not to build such a wall at the end of the "box" but only at the beginning, as in this way the combustible matter and moisture can more readily escape than when the bricks are enclosed on all sides. The rest of the kiln is then filled with bricks set in the ordinary way.

The number of men required depends upon the size of the kiln and the output of the making shops or machines. If the kiln is large enough, three or even four men may be employed in actually setting the bricks, but for most purposes two are all that can work at the same time, and when the output is low a single man may be sufficient. Speaking generally, two men work

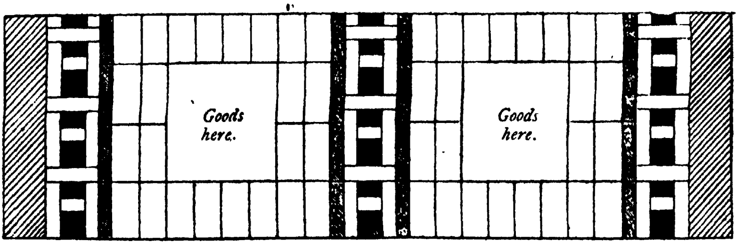


FIG. 242.—Plan of two temporary muffles.

most effectively with an ordinary 14 or 16 ft. chamber, provided they have the bricks placed conveniently near to them by the "wheelers".

Glazed Bricks must be so placed in the kiln that the glazed faces are protected from the flame. Muffle kilns may be used but are costly in fuel, so down-draught kilns are generally employed.

A good arrangement is that shown in fig. 243, and largely used by the author since it was published by L. E. Barringer in 1903. The stretchers or tie-bricks are unglazed, the glazed faces of the headers being set together with a small space between them. These narrow spaces are completely covered at the top and ample protection is afforded to the glaze. To prevent the arrises of the glazed edges sticking to each other, it is often necessary to use short bars of clay between the glazed bricks to keep them ¼ in. apart, or the glazed faces may overhang slightly.

When the setting is complete the kiln door-ways or wickets must be built up with bricks covered with clay paste ("daub") to keep out the air. Sometimes an opening for a fire is left in

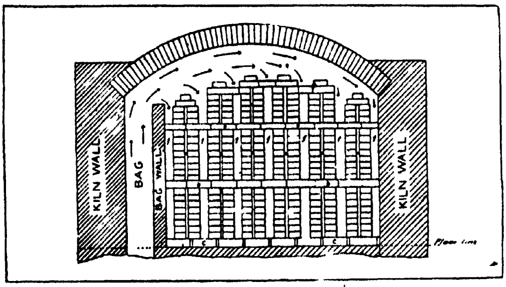


FIG. 243.—Glazed bricks in kiln.

the doorway, particularly with Newcastle kilns, end-fired Scotch kilns, and in continuous kilns where a "wicket fire" is used for the drying of the bricks (fig. 185).

FIRING.

The methods used for the "firing" or "burning" of goods in a kiln depends upon the type of kiln used and on the nature of the goods, but certain general principles apply to all ordinary methods of burning bricks.

The chief requisite for the successful burning of bricks is the steady raising of the temperature to a sufficient height at such a rate that water and combustible materials may escape without damaging the goods, and the expansion and contraction which occur during the heating may take place sufficiently slowly to prevent the strength of the bricks being diminished. This appears a simple matter to those who have no practical experience of brick burning, but in reality it is far more difficult than is usually supposed. Some idea of the amount of skill required may be obtained from the fact that an examination of a very large number of bricks from the most important yards in almost every well-known brickmaking district has shown that less than half the bricks examined were fully or completely burned!

There are, in fact, two distinct heat-treatments possible in brickmaking: (*a*) baking, and (*b*) burning. When bricks are "baked" they are heated sufficiently to rob the material of its plasticity, but they are not durable under very adverse conditions

of climate or use. "Baked bricks" are somewhat soft, and when two are struck together a dull or flat sound is produced, which is very different from the ringing tone emitted when two "burned" bricks are similarly treated. "Rubbers," "cutters," bath-bricks, and ordinary firebricks are typical "baked bricks".

"Fully burned" bricks are characterized by a distinct "ring" when struck, and they do not shrink on further heating except when heated to such an extent that change of shape occurs or the specimens adhere to each other. Some bricks cannot be fired to completion, because the temperature at which they are fully burned is too near to that at which loss of shape occurs. Fully burned bricks are less porous than those which have been insufficiently heated. Engineering bricks and many Midland and Northern bricks are typical "fully burned" bricks.

In order to ascertain the amount of heat necessary to burn a brick completely and the temperature to which it must be raised before it is fully burned, certain tests must be made. These usually consist in making specimen bricks or tiles, measuring them accurately and heating them under carefully regulated conditions to different temperatures. The test-pieces are then examined for shrinkage, porosity, and change of shape, and from the results of this examination a fair idea of the most suitable kiln-treatment can be obtained. In making such tests it is essential that at least one test-piece shall be over-heated so that the highest temperature permissible in the kiln may be known.

A brick is completely burned when it no longer contracts on further heating to a higher temperature,[1] and when its porosity is reduced to the smallest possible amount without the brick losing its shape. There is a tendency amongst certain writers on building construction to assume that only fully burned bricks should be used. This is by no means always the case, as certain effects cannot be obtained with bricks which have been fired to their maximum temperature, and the opprobrium cast upon "baked bricks" by such writers is often quite undeserved. At the same time, it cannot be denied that fully burned and partially vitrified bricks are usually far stronger and more durable than those which have been subjected to a less severe heat treatment.

[1] Accurate measurements will show that contraction never ceases completely, but a stage is reached at which its increase, during a large rise of temperature, is so small that it may be disregarded and the shrinkage considered to have ceased.

In this connexion it is curious that fire-bricks—which are primarily intended to withstand the most trying conditions—are never more than "baked" in this country, though in Germany they are often fired to incipient vitrification. Fire-brick manufacturers would do well to consider this point, which is far more vital to success than many of them suppose.

The following list of maximum temperatures, originally published by Seger, is generally accepted as a standard:—

Goods.	Seger Cone.	Temperature in ° C.
Porcelain colours and lustres	022 to *010a*	600 to 900
Clays rich in lime and iron	*015a* to *01a*	790 to 1080
Brick-clays; red-burning shales	*015a* to *1a*	790 to 1100
Clinkers, paviours, vitrified bricks	*1a* to 10	1100 to 1300
Stoneware; salt-glaze	*5a* to 10	1180 to 1300
Majolica glazes	*010a* to *05a*	900 to 1000
Glazed bricks (hard fire)	*6a* to 9	1200 to 1280
Fire-clay and porcelain	7 to 20	1230 to 1530
Silica bricks; magnesia bricks	16 to 26	1460 to 1580
For determining the refractoriness of clays	26 to 42	1580 to 2000

The figures in the last column are only approximate, and it is always preferable to refer to the number of the cone rather than to the temperature, especially with the higher numbers.

In most cases of clay-burning the exact temperature reached is of less importance than the length of time the goods are exposed to a certain temperature, e.g. whether the maximum temperature is 1250° or 1300° C. matters less than the time of exposure at 1250° C. The essential question is—"Has the heat been acting for a sufficiently long time?"

The finishing temperature for most red-burning clays corresponds to cone 015*a* to 1*a* (790° to 1100° C.), the latter being reached with many red-burning shales. Fire-bricks are usually considered finished at cone 5*a* (1180° C.), but cone 14 (1410° C.) is much more suitable as a finishing point, and far higher temperatures are attained in some Continental fire-brick works.

The maximum temperature to be reached in the kilns having been ascertained, it is necessary to consider the stages which must be passed through before this temperature is reached.

Generally speaking, the burning of bricks must take place in three separate stages, viz. (*a*) drying or "steaming" (sometimes called "stoving"); (*b*) preliminary heating and removal of vegetable and other combustible matter; (*c*) full fire and completion of

the burning. There should, however, be no sudden rise in temperature in passing from one stage to another, and many successful burners do not consciously distinguish between the different stages.

The speed at which bricks can be burned depends on the time needed to pass through these three stages of firing. The first retarder is the amount of water (whether free as moisture or chemically combined) which exists in the bricks when they are first placed in the kiln. With strong, open clays this water may be removed rapidly, but with fine, tender clays several days may be needed for the "smoking" or first stage of burning.

It is not the open or loose clays that dry easiest; aside from openness there must be a natural tenacity of the clay. It must have an inherent strength to withstand the disruptive force of steam. Hence there are two qualities of the clay that will allow rapid water-smoking: (1) open structure; (2) inherent strength. A clay that possesses only one of these must be dried slowly. A clay that does not possess either one has to be dried very slowly indeed.

A further cause of slow firing occurs in the second stage of burning, and is due to the influence of the carbonaceous matter in the clay.

In clays which are rich in organic matter—the Fletton knots for example—great caution is required between the stoving of the goods, which may be said to finish at about 200° C., and the temperature of 1000° C., when the firing will be nearly finished. If the goods are heated too rapidly after the stoving they may "catch fire" and burn too rapidly, and so become spoiled, or they may be burned on the outside and remain black within.

This production of a black core is especially noticeable with certain shales, and with some red-burning clays, and is, in most cases, due to the heating being of too short duration to enable all the organic matter in the clay to be burned out, and for all the iron compounds to have become fully oxidized. It is, indeed, necessary for the fireman to study very carefully the length of time during which it is necessary for him to keep his kiln at one heat—usually at about 900° C., or Seger cone 011*a* or 09*a*—in order that this black core may not appear when a finished brick is broken.

If, when the bricks, or other goods, reach a dull red heat the supply of air to the kiln is insufficient, there is a strong tendency to form the black coring, as the iron in the clay is being reduced

instead of being oxidized (as it would be in the presence of sufficient air), and this lower oxide combines with some of the silica of the clay at comparatively low temperatures, and discolours the goods considerably. In addition to this, gases are often given out by the slag thus formed, and the goods are cracked or "blown".

The pores in clay being very small, and the amount of free air in the flue-gases not being in large excess, a considerable time is often required before the black core is all "burnt out," and in some of the worst clays the kiln must be kept at or near 900° C. for 100 hours or more before it is safe to allow it to rise higher and then finish the kiln. Fortunately, the time required for this stage of firing is not usually so long, but the stage is usually well marked in most clays, and may, for convenience, be termed the "second" or "oxidation" stage of the burning, the first stage being the "smoking" or "stoving".

If the heat has been carried on to the vitrification point, without sufficient time having been taken at a lower temperature to burn out the carbon, it would swell the bricks. In the case of one fire-clay it is necessary to hold the heat at 500-800° C., that is, several degrees below redness, for seventy hours, before all the carbon is burned out. A drift-clay or glacial-clay found close by can be burned out in ten hours under the same conditions. Some clays will readily permit of the burning out of the carbon, some require a greatly extended time.

Hence the rapidity with which clays can be burned depends largely on the clay. Because one man's material may require a longer time, it does not follow that another cannot burn his clay in less. In some descriptions of kilns, in which the patentee claims that he can burn several thousand bricks in one or two days' time, it will be noted that the specifications invariably state that they will "finish the burning in two days". That means that they have given the clay a pre-heating in order to burn out the carbon and dehydrate the clay, so that the time required "to finish burning" the bricks is spent wholly in "completing," i.e. in developing colour or vitrification.

The speed at which the fire travels forward in a continuous kiln cannot, therefore, be stated with accuracy, though it should not, in ordinary cases, fall below an average speed of 11 to 12 ft. per twenty-four hours, or 6 in. per hour, this measurement including all the different stages of firing. With a suitable kiln ten times this rate of fire-travel may be obtained under good conditions.

The speed of the firing will depend on (*a*) the nature of the clay or goods, and (*b*) the draught or air-supply, and the latter must be regulated chiefly by the former. If the goods will stand a quick fire without damage, the more rapidly they are burned the better they will be, but all attempts to hurry the fire faster than the goods can stand will end in failure to produce satisfactory goods.

By using a continuous kiln of very great length and small width (as suggested by Bührer) it is possible with open clays, relatively free from vegetable or other carbonaceous matter, to burn five or even ten times as fast as is usual in this country, but a highly skilled burner is necessary for this purpose.

Drying or Steaming.—No matter whether bricks have been dried or not before entering the kiln, they always evolve a large amount of water before they become red hot. The proportion of water varies with the amount of clay in the material, but is seldom less than one-sixth of the total weight of the brick. In other words, in spite of the most careful drying, a pound of water must be removed from ordinary bricks before they are heated to redness. The elimination of this water (some of which being "combined" with the clay cannot be driven out by drying) is one of the most delicate operations under the control of the burner, as, if it occurs too rapidly, the bricks will be seriously weakened by the excessive pressures caused by the large volumes of steam produced within the pores of the bricks.

This "kiln drying" may be accomplished by the use of waste heat from other kilns or chambers (as in a continuous kiln, where the heat from the cooling bricks is often employed), or wicket fires (fig. 185) or stoves may be used. In single kilns the fires are lighted in the fireplaces and are allowed to smoulder so that the warming takes place very gradually, the fire being allowed to burn more brightly after two or three days. A similar procedure takes place when wicket fires are used in continuous kilns, a small opening being left in the door-gap into which glowing coals are placed or in which a small fire is lighted with chips, paper, and coal.

Instead of a fire lighted in the wicket of a continuous kiln, a portable stove is sometimes used, whence the term "stoving" for this operation. Such a stove saves fuel and the trouble of lighting many fires (fig. 187).

The drying, or steaming, must be continued until the whole of the combined water has been removed and the goods are

distinctly hot. With most clays this cannot be considered to be complete below a very dark red heat, and by the time the bricks have reached this temperature a large part of the vegetable and other combustible matter will have begun to decompose, and the bricks will have entered upon the second stage of burning.

In continuous kilns the first stage is usually considered at an end when the goods have reached a temperature of 120° C. (as shown by a thermometer lowered in the kiln); but the attainment of this temperature really only indicates that the goods are sufficiently hot for the waste gases from previous chambers under fire to be passed through them. This is very different from saying that the goods are really dry or that all the steam has been removed!

The completion of the "steaming" is usually tested by placing a long, cold iron bar into the kiln or chamber and withdrawing it after a few seconds. If much steam is present the bar will become damp, but the test is a very crude one and far from being satisfactory.

A much better plan consists in lowering a suitable thermometer, protected in a metal case (fig. 244), into the kiln by means of a light chain, and reading the temperature when the thermometer is again withdrawn. The metal case serves to show any condensable water vapour in the kiln, and the thermometer, by indicating the temperature, shows the burner whether it is safe to fire more vigorously.

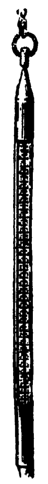


FIG. 244.—Kiln thermometer.

Owing to the large volumes of steam produced during the first stage of burning, the kiln should have several openings through which steam may escape. Some bricks are sufficiently strong to enable the steam to be drawn away through flues, but with delicate clays draughts must be avoided as much as possible.

There is much difference of opinion as to whether the steam should be removed from the upper or lower parts of the kiln. As the damp air is specifically heavier than when it enters the kiln (because the contraction due to loss in temperature is greater than the increase in volume caused by the water vapour) the theoretically best method is to withdraw the steam from the bottom, but as the constant contact of the lower bricks with moisture tends to soften them (as they have to carry the weight of the bricks above them) it is, on this account, often necessary to remove the steam from the upper part of the kiln. In certain

modern continuous kilns the steam may be removed from several parts of the chamber simultaneously.

When the bricks are not sensitive to air-currents they can most safely be dried and heated by passing hot air through the kiln or chamber.

Volatilization or elimination of combustible matter forms the second stage in burning bricks, but the changes which occur in it are often exceedingly complicated. Thus, it is not merely that certain materials are volatilized, but the combustion of vegetable and other matter in the clay takes place at this stage, and the colour of the bricks is often seriously affected if this portion of the burning is unduly hurried.

As is well known, the colour of red-burning clays is largely due to the presence of red iron oxide, a material which is very sensitive to partially burned vegetable matter. Thus, if mixed with vegetable matter and rapidly heated with a limited supply of air, bricks containing much iron oxide will have a bluish or slag colour when taken out of the kiln, as the vegetable matter acts as a reducing agent and prevents the formation of the red colour, unless the conditions required for its production are all present. Many discoloured bricks and most bluish "cores" or "hearts" in bricks, which should burn to the same colour throughout, are due to the presence of carbonaceous matter which has been heated too rapidly and with an insufficient amount of air.

To burn a brick to a good colour throughout, it is necessary to have an ample supply of air in contact with each particle of the brick, so that any iron compounds present may be completely converted into the red oxide. With some particularly difficult clays alternate heating, with and without air, may be necessary before this red iron oxide can be obtained.

Most burners make the mistake of using too little air and of heating too rapidly when the goods are at a temperature of 750° to 950° C.; and if a brick when broken shows a distinct core, the kilns in which other bricks of the same material are burned should be kept for some hours at a temperature of about 900° C. (dull red), with an ample supply of air and a clear burning fuel, until it is certain that all the core-forming material has been burned out. If once the temperature is allowed to become so high that partial vitrification sets in, the core can never be removed by prolonged burning, as the pores of the brick will be closed and air cannot get to its interior; for this reason, it is

essential that the heating should be very steady during the second stage of the burning.

The time required for this second stage varies greatly with different clays. With some very open materials it may be passed in ten hours, but with dense clays containing much iron and some organic matter it is necessary to keep the bricks at a dull red heat for four or even five days if cores are not to be formed. The most difficult clays to deal with at this stage are those (such as some shales) which contain a certain amount of "fuel" intermixed with the clay.

The method of manufacture has a great influence on the time taken for this second stage of burning, and a dry-press brick being often less dense than one made from plastic clay will be correspondingly easy to fire. Occasionally, however, a dry-press brick of exceptional density is obtained and is very troublesome. Probably no clay exists which cannot be burned properly at this stage, but if the time required is excessive, the cost of treatment may make it prohibitive from a commercial point of view.

Clays which contain pyrites, or other iron and sulphur compounds, are particularly troublesome at this stage, as the sulphur acts as a reducing compound and tends to form an iron slag, unless the heating is exceedingly slow and tedious and the clay of a very porous character. This slag often fills up the pores, and prevents a well-coloured brick being produced.

Blue bricks are burned with a minimum quantity of air at this stage, as the formation of a slag is desired in order to bind the clay particles thoroughly together. This is, however, a special case.

For ordinary buff- and red-burning bricks, it is highly important that, during the time in which they are at a temperature of 750° C. to 950° C., they should have an abundant supply of air and no smoke, and that the temperature should not be raised above a dark red heat until it is fairly certain that the iron has been fully oxidized and all combustible matter removed. Unless this is done, and the oxidization is completed before vitrification sets in, the formation of "cores" or "hearts" is almost certain to occur.

When clays are burned at temperatures approaching 1200° C., it is practically impossible to admit any excess of air without a special regenerator, and consequently it is impossible to prevent an occasional reduction at this temperature. This will not

matter much if the clay has been properly oxidized at 900° C., or thereabouts. On the other hand, it may generally be assumed that goods not oxidized at or near this temperature will never be oxidized.

In some cases where irregularly coloured bricks are required, it is usual to heat with and without air alternately. This operation is known as "flashing" and is begun towards the end of the second stage of heating. By heating with a smoky flame and but little air a bluish shade is produced, and this is partly destroyed and replaced by a red shade when the bricks are heated with plenty of air. The combined shades are sought by some architects and builders who do not like the "monotony" of walls made with evenly coloured bricks. In some yards this alternation of heating is done more or less unconsciously by the burners, as in the manufacture of "purple" sand-faced bricks, which lend themselves readily to such treatment. When blue bricks show patches of red on them it is a sign that too much air has been used at some stage of the burning. Clay which has been mixed with coal or sawdust needs specially careful firing at this stage.

A brick which has been properly fired to the end of the second stage will, if broken, be of uniform colour throughout the whole cross-section, but it will be soft and weak. If, on the contrary, it has been hurriedly fired, or with too little air, it will show a spot of dark colour on the broken face, the size of this spot depending on the incompleteness of the air-supply. In some instances a broken brick shows only a narrow border oxidized, the whole interior of the brick being unaffected, whilst another, which has been better treated, may only show an unoxidized spot.

Full Fire is the stage at which the bricks are finally heated, the object being to cause sufficient vitrification to form a solid and durable brick. In "baked" bricks (p. 337) this stage is never reached, as the firing of such bricks is ended at the close of the second stage, or very early in the "full fire" stage. The full firing is not complete until the goods have entirely ceased to contract without losing shape (and would not do so even if heated 150° C. or so higher), and when some amount of fusion of certain constituents has taken place so that the maximum available density is reached. This is somewhat lower than the absolute maximum density, which only occurs after the bricks have lost their shape, and so is useless for practical purposes.

Thus, if a brick or tile made from a clay is found to absorb 15 per cent of water when fired at cone 022, and only 12 per cent

at cone 020, and if, no matter how much hotter it is made, the absorption never sinks below 10 per cent without the clay losing its shape, it is clear that for all practical purposes the best finishing heat is somewhat above cone 020.

When clays are subjected to a sufficiently high temperature a certain amount of fusion takes place, some of the ingredients melting and binding the others together in a more or less vitrified mass. When this fusion commences, the clay has softened sufficiently to make the grains stick together, but the particles have not fused sufficiently to close up all the pores of the mass nor to allow a recrystallization. The broken mass of the clay shows a dull surface, with laminations more or less distinctly evident in the mass, with many isolated particles showing no heat effect. If the burning is arrested at this stage the resultant mass will be slightly softer than steel, will absorb water quite readily, and will disintegrate under the continued absorption of alkaline and acid liquids. It is then said to be in a state of incipient vitrification.

Under a continual and gradual increase of temperature the clay granules undergo an additional softening, sufficient to close up all the pores and render the mass impervious, owing to the production of a larger amount of fused matter. Clays burned to this condition show, when broken, an extremely hard surface with a smooth fracture, having a slight lustre and showing no laminations. The substance will not be scratched with steel, is impervious to water, and is completely vitrified. After the vitrification period is passed a sufficient rise in the temperature causes swelling and softening of the clay, until it leaves its original form and flows into a viscous mass. Upon cooling, the substance may crystallize partially, but usually forms a dark, glassy mass.

The speed at which the temperature rises during the period of full firing may be much greater than during the earlier stages, providing that it is sufficiently under control for the bricks not to be over-heated. This qualification is necessary, because in some clays the finishing point of the firing, and that at which the bricks lose their shape and are spoiled, are not far apart, and if the heating of the kiln at the last is very rapid, many bricks may be spoiled by the inability of the fireman to keep the temperature within the necessary limits.

Some burners allow the temperature inside the kiln to remain constant for a long time previous to finishing, and this is desirable in some cases. In many instances it is, however, undesirable and unnecessary, as any such "soaking" should have been done.

at a temperature not exceeding that of a dull red heat (say 950° C.), and not immediately before finishing the firing. So much depends upon the nature of the clay and the effect which it is desired to obtain by the action of heat that no general rule can be laid down, beyond the one that the temperature should increase steadily and its rise must be under complete control.

The firing of a clamp kiln has already been described (p. 65). When once started, such a kiln needs no further attention as it burns itself automatically.

Single kilns of all types are started by lighting a fire in the various fire-places, taking care to allow it only to smoulder for some time so that the first heating is not too rapid. Later the fires are stirred so as to open them out, and by more vigorous stoking they are caused to burn with steadily increasing intensity until the bricks are finished.

The mouths of the fire-boxes should be kept sufficiently open to allow the requisite amount of air to enter (unless special air-ports are provided), but care should be taken to avoid either too much or too little air. The faulty construction of many fire-boxes is responsible for much waste of fuel, and as a general rule the air needed should be supplied exclusively through the grate, with the exception of that needed immediately after each fresh charge of fuel. This supplementary air should be supplied through a special series of openings which can be closed when not required. The common plan of working without doors and with shallow fire-boxes is wasteful in fuel and should be changed as soon as circumstances permit.

The chief precautions to be observed are those already mentioned, but when down-draught kilns are being fired the goods in the bottom of the kilns will be under-fired, unless special care is taken to admit air to the upper portions whilst continuing the heating of the lower. The reason for this is the peculiar way in which coal burns. Instead of being a simple matter, as many burners appear to suppose, the burning of the fuel takes place in two distinct stages, viz. the burning of the gas and the burning of the solid fuel. When a fresh lot of coal is placed on a fire the heat of the fire converts part of the coal into gas and smoke, and if sufficient air is supplied both these substances will be properly burned. As soon as the gaseous portion is all driven off, the solid part of the fuel (coke) needs a smaller supply of air per minute for its combustion, and unless some arrangement is made for regulating the air supplied to the fuel, too much air will enter the

fire-box during the burning of the coked fuel, or too little air will be supplied during the evolution of the gas and consequently the kiln will smoke.

To secure the best results, the air supplied should be heated to at least 500° C., but few kilns have facilities for this purpose. Yet unless hot air is used, at any rate during the production of gas from the coal, it is very difficult to avoid the production of smoke. The author has used successfully a vertical flue running through the walls of the kiln above each fire-box, the air being drawn in through an opening near the top of the kiln, its quantity being regulated by a simple slide-damper. Some arrangement should be made whereby this hot air can be passed over the surface of the fuel in the fire-box or underneath the grate, the ash-pit being kept closed.

The distribution of the heat in a down-draught kiln is facilitated by using a kiln with a perforated floor. If this has not been made at the same time as the kiln, it can usually be added at a trifling cost afterwards.

The chief precautions in firing a down-draught kiln are those already mentioned in this chapter, as referring to kilns in general, but there is always a risk in down-draught kilns of the goods in the lower portion being under-fired, unless special care is taken to admit air to the upper parts whilst still continuing to heat the lower ones. This is known as "getting up the bottom," and is an operation needing much skill.

Broadly speaking, the firing of a down-draught kiln will be successful in proportion as the burner is able to recognize the varying temperatures in the different parts, and is able to work his fires accordingly. To do this effectually he must pay special attention to the appearance of the different parts of the kiln, but especially to that of the upper and lower ones. The firing of a down-draught kiln is, however, an operation which requires so much practice and judgment that it is impossible to describe it in detail.

The "finish" or end of the firing of a single kiln may be accomplished by closing all the fire-place mouths and other openings with bricks, or slabs, so as to exclude all air except such as may leak through the brickwork, or the fires may be drawn out of the fire-places previous to closing these as just described. The author prefers an intermediate method, and opens out the fires with a poker immediately the goods are sufficiently burned, so as to allow the fuel to burn up rapidly

but with so much air that the temperature of the kiln does not increase. When the fires have died down he closes the holes, more or less completely, according to the nature of the goods, leaving the damper connected to the chimney as widely open as the circumstances of the case permit. In this way it is often possible to get a better colour than when the kilns are closed completely immediately after the firing, and danger of cracking the goods is negligible if care is taken not to allow too much cold air to enter at one time.

Bricks can often be improved greatly in colour if, when the firing is finished and the kiln "closed up," a number of openings are made in the front of the kiln about two hours after the completion of the "closing". These openings should be small and numerous rather than large and few in number, and they should remain open for about an hour or ninety minutes, so that sufficient air may enter the kiln to "brighten up" the goods. The holes are then closed, daubed up with clay, and the cooling of the kiln allowed to proceed in the usual manner. It is remarkable what a difference in the appearance of the bricks is produced when this simple dodge is resorted to with the majority of clays. The improvement is probably due to the fact that the discolorations of bricks are mostly due to their being heated in a reducing atmosphere, whereas when this air-supply is used after the finishing of the kiln, these discolorations are removed by the oxidizing action of the air admitted.

Newcastle kilns often differ from other single kilns in having no grates on which the fuel is fired. Opinions differ greatly as to the advantages and disadvantages of grates, particularly during the third stage of firing, where the coal is liable to clinker badly. On the whole it may be said that grates are best when but little clinker is produced, as they enable the fuel to burn more economically. Even when much clinker is liable to form, the presence of a pan of water or a steam jet beneath each grate will often reduce the amount produced, and in other (bad) cases the fuel should be fired direct from the ground, the waste of fuel being less serious than the waste of time involved in removing the clinker. For burning building-bricks in Newcastle kilns, grates should invariably be used. For fire-bricks—where the heat is more intense—grates are often a nuisance, unless the fuel is burned in a gas-producer.

The burner may know when to cease firing his kiln by (*a*) determining the temperature by means of Seger cones or some

other pyrometer, or (*b*) by determining the amount of shrinkage which has occurred. This latter is the most popular method at the present time, but progressive burners are utilizing it in connexion with some form of draught-gauge or temperature recorder as (*a*) so as to secure more uniform results.

The usual method of measuring the shrinkage is by means of a metal rule which is pushed through a hole in the top of the kiln from time to time, the heating being continued until the bricks have settled to a predetermined amount which varies with the clay, but is usually about 1 in. per ft.

Unfortunately, the amount of shrinkage or settling is often influenced by the proportion of water in the clay paste used for making the bricks, and can only be regarded as a rough guide in finishing the kiln. Some firms use small, accurately made trial pieces which they draw from the kilns, and measure very accurately so as to determine the shrinkage. This method is little if any better than the simple use of a measuring rod as described, as far as firing bricks is concerned. Seger cones are superior for this purpose when properly used.

The firing of a continuous kiln is a matter requiring special care and attention, as failure to keep a sharp look-out on what is going on in each chamber may result in disaster. The number of dampers and valves in a modern continuous kiln is often large, and a man of considerable intelligence is needed to produce satisfactory results.

There is no greater difficulty in firing a continuous kiln than is found in burning an equal number of separate chambers, and the labour required is far less, as for the greater part of the heating of any chamber no attention is required at all, if the kiln is properly built and is sufficiently long. Hence, when a burner once gets accustomed to continuous kilns he seldom cares to fire single ones.

In a continuous kiln the main object is to make as much use as possible of all the heat available, by passing the products of combustion from one chamber through a number of others before admitting them to the chimney. This arrangement secures a great saving in fuel but must not be carried too far, or the goods will be spoiled by "scum". This scum is caused by the moisture in the gases condensing on the freshly set goods and the acid vapours dissolved by the water thus formed. It is, therefore, essential that hot air, free from moisture and fire-gases, should be used for drying bricks and raising them to a

temperature of 120° C. in a continuous kiln. When above this temperature little or no condensation can occur, and the formation of scum is thus prevented. The precise means used for the supply of warm air for this purpose depends on the design of the kilns used; usually air is drawn through chambers filled with bricks which have finished firing. The air passing around the cooling bricks becomes heated and is then taken to the freshly set chambers, being mixed with sufficient cold air to prevent the new bricks from being damaged.

When no such supply of warm air is available some form of stove or a wicket fire must be used, or, if the kiln is one provided with grates, the fuel may be placed on these. In some modern kilns, special flues for the heating of air are employed (pp. 272 to 275 and 297 to 299).

As soon as the bricks in a chamber have all reached a temperature of at least 120° C. the special heating is stopped, and, by an arrangement of dampers, the chamber thus prepared is placed in the regular circuit of the kiln, the fire-gases passing through it before entering the chimney-flue. The number of chambers through which the fire-gases pass should not be less in total length then 56 to 70 ft., or, say four or five chambers, each 14 ft. long, unless some very unusual conditions prevail. No fuel is used in these chambers; they are heated exclusively by the waste heat of the fire-gases until they reach a later stage in the firing.

The use of fuel is confined to about 40 ft. in length or about three chambers, so that a successfully fired continuous kiln of medium length (sixteen chambers) will always have one chamber being filled, one chamber being emptied, three chambers cooling and supplying warm air to the freshly set goods, three chambers supplied with fuel and nearing the end of firing, five heated with fire-gases only, and three freshly-set chambers heated by wickets or warm air. If more chambers are available the number heated with fire-gases and fuel may be increased, and two chambers may be filled daily instead of only one.

If there are fewer chambers, as, for instance, in a fourteen chamber kiln, the temperatures in each chamber will be somewhat as follows:—

No.	1	chamber	"Smoking"	15° to 120° C.
,,	2	,,	,,	,,
,,	3	,,	Heating	120° to 200° C.
,,	4	,,	,,	200° ,, 400° C.
,,	5	,,	,,	400° ,, 600° C.
,,	6	,,	,,	600° ,, 700° C.
,,	7	,,	Being fired	700° ,, 880° C.
,,	8	,,	,,	880° ,, 1057° C. (Cone 02*a*)[1]
,,	9	,,	Cooling	1000° ,, 600° C.
,,	10	,,	,,	600° ,, 360° C.
,,	11	,,	,,	360° ,, 160° C.
,,	12	,,	,,	160° ,, 50° C.
,,	13	,,	Being emptied	"Cold"
,,	14	,,	Being filled	,,

The temperature, etc., of each chamber may also be shown diagrammatically as in fig. 245 which is a slight modification of an illustration published by J. Osman & Co., Ltd., for their "New Perfect" kiln, but which is equally applicable to any continuous kiln with the same number of chambers.

14. Being filled.	13. Being Emptied.	12. Cool.	11. Cooling.	10. Cooling.	9. Cooling.	8. Being fired.
1. "Smoking" or "Drying".	2. "Dry."	3. Hot.	4. Black Hot.	5. Nearly Red Hot.	6. Red Hot.	7. Being fired.

FIG. 245.—Method of working continuous kiln [1]

The firing of a continuous kiln takes place in three stages, viz. (*a*) "smoking" or "drying"; (*b*) heating by waste heat from other chambers; and (*c*) full fire, but each of these may be subdivided where troublesome clays are burned.

The *smoking* or drying in a continuous kiln is not carried so far as in a single one, for as soon as the contents of a chamber have reached a minimum temperature of 120° C. they may pass to the second stage of heating.

"Smoking" may be accomplished by wicket fires, stoves, or the use of hot air from other chambers in the kiln, the last named being preferable in every way when the supply of hot air is sufficient, and providing that its temperature can be regu-

[1] Some variation of these figures must, however, be permitted, owing to the widely different treatment required by some clays.

lated with sufficient accuracy. To use this hot air (produced by drawing cold air through the chambers containing bricks which it is desired to cool, or through special air-heating flues above the arch or below the floors of other chambers) the necessary valves or dampers in the kiln are so placed as to deliver the air where it is needed, a supply of cold air being added if necessary. When once the dampers have been placed in their proper positions the bricks are warmed automatically, and the burner has only to regulate the amount of air admitted, so that the temperature of the freshly set bricks increases at the desired rate.

The construction and arrangement of these hot-air flues have been made the subject of numerous patents, and whilst they differ from each other in many respects, they have many features in common, and the diagram shown earlier (fig. 193) of the "Manchester" kiln (Dean, Hethrington & Co., Leek) includes the chief features of them all. The chief difficulty to be overcome lies in the enormous volume of steam and air to be drawn through the chambers during the smoking, and in not a few cases kilns have failed to work successfully for no other reason than that the designers did not allow sufficient flue-space for this purpose.

As will be seen from the illustration (fig. 193) the smoking may take place in either an upward or downward direction, according to the nature of the goods and the wish of the fireman, though in this particular instance the air from the cooling chambers is only shown as coming from the hot air flue S. From S the hot air passes to below the grate of the chamber, up through this—the grate in this kiln being similar to that in the Belgian and other kilns in which the fuel is kept out of contact with the goods, by being fired on a special flat grate—into the chamber A, where it dries the damp goods. The steam and hot air then rise upwards, as shown in chamber B (which is a section farther along the same chamber), until it escapes through large holes in the roof to the space between the two arches with which this type of kiln is furnished. From the arch the steam passes through a large flue to the chimney stack, as indicated by the arrows in the illustration.

This arrangement of a double arch to the chamber enables flues of ample size to be constructed so that the steam may be drawn off as rapidly as is desired, and the same arrangement enables an equally abundant supply of hot air to be supplied from the cooling chambers to the flue S, from which it may be transferred to any chamber needing it. When delicate clays are

being dried or smoked the opening of the "cold air valve" permits of air of any desired coolness being admitted to the chambers. This admixture of cold air is of enormous value in some cases, and kilns possessing arrangements for producing it are consequently better than those without it when high-class goods are being fired.

In many continuous kilns there is no provision for using air in this way, the air passing over the cooling bricks being used for the main fire or being wasted. In such cases wicket fires or stoves must be used, or, if the kiln is provided with internal grates these may be used instead. Grates may be built in the wicket if desired, but a commoner plan is to burn the fuel on the ground (fig. 185), a poke hole (*a*) and another (*b*), about 1 ft. square, being left through which fresh fuel may be added. The fire must smoulder or smoke for many hours so as to prevent the bricks being over-heated at first, the chamber being separated from those on either side of it by iron or paper dampers, and the damper connecting the chamber to the main flue being kept open. At the same time it is often wise to open the feed-holes in the top of the kilns, unless special flues are provided for the removal of the steam.

When the bricks have reached the requisite temperature (120° C.) or when the fireman judges they are sufficiently heated, the holes in the wicket are built up and the heating is continued by the breaking down of the paper damper, or the removal of the iron one, and the consequent admission of hot gases from the next chamber. The damper connecting the latter to the chimney is closed.

In many kilns wicket fires are unsatisfactory, because the heat is so unevenly distributed throughout the chamber and the amount of unwarmed space (dead space) is often very large. This objection may be partly overcome by the setters constructing a series of flues through the bricks, but some amount of unevenness appears to be inevitable.

A better plan (though not as satisfactory as the use of warm air) consists in the use of a number of small stoves which fit into the feed-holes in the arch of the chamber (fig. 187) and through which air, heated by the fuel in the stoves, is drawn down into the kiln. The number of these stoves needed at one time varies with the nature of the clay; in many cases a stove should be placed in each feed-hole of the chamber to be warmed. As the chamber dries a row of stoves is taken to the next chamber.

With delicate clays a single row of stoves may be used. One objection to the use of these small stoves is the condensation of moisture which is liable to occur on the bricks in the lower part of the kiln, thus softening and spoiling them. This objection is more apparent than real in many cases.

In order to ensure the whole of the contents of a chamber having a minimum temperature of 129° C. it is desirable to use a thermometer enclosed in a brass tube, in which a slit has been cut so that the thermometer may be easily read (fig. 244). By lowering this thermometer into different parts of the chamber by means of a thin chain, and after a short interval withdrawing it rapidly and reading it, very satisfactory results can be obtained, providing that the thermometer is sufficiently slow acting, or has some self-registering arrangement so that its readings are not affected by the time taken to withdraw and read it.

Unfortunately the thermometer is often used carelessly, and many badly smoked chambers result when this is the case, as the thermometer is not a "regulator" but merely an "indicator" of what is going on inside the chamber, and if its indications are disregarded, or if its employment is carried out superficially instead of thoroughly, well stoved goods cannot be obtained.

The best part of the chamber for testing with such a thermometer is as close to the sole as is possible without the thermometer actually touching it, but temperature readings should also be taken at different heights in the chamber, because the difference in temperature is often very considerable, and particularly so when the goods to be fired are very damp. This is one reason why goods should not be placed in the kiln unless they are as dry as possible, as irregular heating, even during the smoking, is not desirable.

The difference in temperature between the sole and top of the chambers undergoing smoking varies with different kilns, but there appears to be a definite relation between the height of the chamber, the draught of the kiln, and the proportion of moisture evaporated per minute from the goods, though this relationship has not been accurately determined.

It is a rule, common in many brickyards, that the smoking must not be stopped until the lowest temperature in the chamber is 120° C., but when very wet goods are set it is almost impossible to carry out this rule without seriously delaying the kiln, as until all the moisture has been driven out from the goods this temperature cannot be obtained, and the temperature at the sole of the

chamber may easily register 700° C. or even show signs of redness whilst the upper goods are still at a temperature of only 100° C. Thus, it is not uncommon to find that a piece of newspaper will catch fire if thrown into one part of a smoked chamber whilst another part will (on account of the dampness of the goods) still have a temperature lower than that of boiling water! In such cases the use of paper dampers between the chambers is unsatisfactory, because the paper is destroyed before the whole of the chamber is properly smoked, and sometimes the accumulation of condensed moisture on it is so great that the paper softens and falls.

It will generally be noticed that the unevenness in temperature is greatest when the ventilation of the chamber is low, and the rate of drying or steaming is high, as the moisture causes irregular currents in the chamber, and the accumulations of water-vapour which occur are difficult to dissipate unless some vent is given. In some of the more recent forms of continuous kiln, special steam vents are arranged for this purpose, but even when these are absent much may be done by opening the caps of four or five feed-holes in the arch of the chamber, so as to allow the steam to escape, or, if the draught of the kiln is strong enough, to draw a current of air through the chamber.

The *second stage* of heating in a continuous kiln needs little comment. The temperature of the bricks must not be allowed to rise too rapidly and an ample supply of air must be admitted in order to burn out the carbonaceous matter in the clay, but if these points are watched, and the precautions mentioned in the section on firing single kilns from 800° C. to 950° C. are observed, no difficulty need be anticipated.

The gases used at this stage of the firing are carried forward through one chamber after another until their temperature is reduced to about 200° C. or even less. They must not be used when below 150° C. however, or they will cause condensation products to form on the goods and they will not rise readily up the chimney. The temperature at which these gases are admitted to the chimney will, therefore, depend on the draught required in the kiln and on the number of chambers available. As the fire travels forward, the time will eventually come when a fresh chamber has to be heated by fuel and it thus passes into the third stage of firing.

The *full fire* or third stage of burning in a continuous kiln requires care and skill. The manner in which it is conducted

depends largely upon the construction of the kiln. Thus in the original Hoffmann kiln small fuel is fed in through the feed-holes in the arch and lodges on projecting pieces of brick in the fire-shafts placed there for that purpose. In this type of kiln, therefore, the fuel is scattered amongst the bricks to be burned. The fuel is added in very small quantities at a time, in accordance with the old maxim to "fire lightly but often". If the burner should try any other method to save either himself or the coal, trouble is sure to result. The bricks should not be fired until there is sufficient heat in the chamber to ignite the fine coal or "duff" which is generally used in the burning of continuous kilns. If care is not taken in this matter, the fine coal will immediately turn to coke, and choke the trace-holes, stopping the draught and spoiling the bricks against which the coke rests. The quantity of coal used per thousand will vary according to the nature of the clay, but should not exceed $3\frac{1}{2}$ cwt. per thousand (common) bricks in a well-designed kiln.

The author's personal experience is that every continuous kiln requires careful and regular attention to make good work, and to get the most out of it. It must be fired very regularly and very lightly; by no means must a flue get blocked or have a large quantity of fuel in it.

To get the greatest quantity out of a kiln a regular draught should be maintained, and as long a length of fire as the kiln will allow. The fireman must be constantly feeding; he should not put down more in each hole than it will consume by the time he gets to the last, so that he commences again at the first as he leaves at the last, and should just keep sufficient up-draught to burn the bricks on top. He should work in a contrary direction to that in which the fire travels, or the smoke from the last-fired holes will prove troublesome.

If a continuous kiln travels slowly, a quantity of coal or cinders collects in the bottom; this means black-ended bricks. It is often as well, if there is anything on the bottom, to stir it with a rod after the bricks have got below burning heat. The back rows should be left at as near a burning heat as possible, then the coal will all burn away, and leave the kiln bottom clean and the bricks free from black ends.

The whole secret of successful burning is attention and regularity.

In the more modern types of continuous kiln a series of grates running from front to back is used. This arrangement, first intro-

duced in the "Belgian" kiln, has become very popular, as it makes both setting and firing much easier and the heating is more under control. The fuel may be fed on to the grates through openings in the front of the kiln or through the usual feed-holes in the arch, some burners preferring one and some the other method. Air for the combustion of the fuel may be supplied direct from the atmosphere to below the grate, or special flues may be used. To some extent air from the chamber last finished firing may also be employed.

The fuel on the grate should be kept at one depth, and fresh fuel should be added in small quantities at a time, as, if too large a quantity of coal or fuel is added at once, the cooling effect it produces will cause the violent production of smoke and the waste of much heat.

When properly fed with a fair quantity of coal, the combustion is so complete that no clinkering is needed during the heating of the chamber. The small quantity of ash produced may be removed when the bricks are drawn from the chamber.

By working with a fair depth of fuel the conditions usually met with in a producer are obtained, and in consequence there is but little advantage to be gained by the installation of gas-producers when a kiln of this type is used.

The accurate control of temperature in kilns has only been attempted by a small number of brickmakers in this country, and the majority of burners estimate temperatures by the eye (which is often defective, though in many cases remarkably accurate), and decide that when the shrinkage of the bricks has reached a certain amount it is time to cease firing.

Whilst these "guides" are quite accurate enough for the manufacture of common bricks from many clays, they are far from being reliable with more delicate materials, and other means must be adopted.

For most purposes the use of Seger cones is to be recommended, as these are simple and cheap in use (costing only 1d. each) and are very reliable. Such cones do not register temperatures so much as the result of heat action, but as the latter is what the brickmaker wishes to know, cones are often more valuable to him than a pyrometer would be, and this in spite of the fact that the prolonged action of heat at a certain temperature will bring down a cone which is only rated to fall when subjected to a higher temperature. "Thermoscopes" are bars which "sag" on heating.

Seger cones are pyramidal pieces of partially burned material

resembling easily fused porcelain (fig. 246). They are made from various mixtures of clay and fluxes under very careful supervision, and are rigorously tested before being sent out. Similar cones by other makers are occasionally offered for sale, but should be avoided unless the conditions of their manufacture are known or their reliability can be guaranteed.

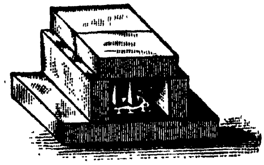


FIG. 246.—Method of placing Seger cones.

Seger cones are so constructed that when one is embedded in a stiff piece of clay paste to the depth of one-eighth inch or rather less it stands upright until it has been heated to a given temperature. It then bends over until its point touches the clay base, and if still further heated it melts. The temperature indicated by the cone is that at which its point just reaches the level of the base (fig. 247). A lower temperature will not cause it to bend so much as this, and a higher one will cause it to collapse. The cones are sold to indicate differences of 20° C. for

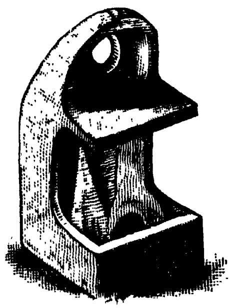


FIG. 247.—Seger cones in "case".

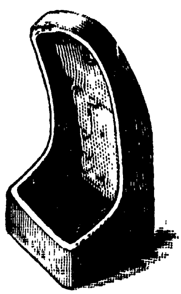


FIG. 248.—"Case" for holding Seger cones.

all temperatures from just below the earliest visible red heat to those at which the most refractory clays melt.

The cones are placed in different parts of the kiln at various heights in order that they may enable the burner to secure regularity of heating. At first a larger number of cones will be required, but later (as the burner becomes accustomed to their use) three different numbers of cones in each part of the kiln will be sufficient.

Of these three numbers, one is intended to act as a "warner,"

showing that the finishing temperature of the kiln is being approached, the second is intended to show when the kiln has reached the correct finishing point, and the third is to indicate (when the kiln is drawn) whether any over-heating has taken place.

The cones must be so placed that they can be seen through spy-holes placed in the walls of the kiln (these holes being normally plugged with blocks or pegs sealed with clay paste) and the cones should not be too near the outside of the kiln. In most cases, the arrangement shown in fig. 246 is satisfactory; but, if preferred, a "case" (figs. 247 and 248) may be used.

The range of temperature covered by these cones is shown in the following table:—

No.	Cent.	No.	Cent.	No.	Cent.	No.	Cent.
022	600°	07a	960°	9	1280°	29	1650°
021	650°	06a	980°	10	1300°	30	1670°
020	670°	05a	1000°	11	1320°	31	1690°
019	690°	04a	1020°	12	1350°	32	1710°
018	710°	03a	1040°	13	1380°	33	1730°
017	730°	02a	1060°	14	1410°	34	1750°
016	750°	01a	1080°	15	1435°	35	1770°
015a	790°	1a	1100°	16	1460°	36	1790°
014a	815°	2a	1120°	17	1480°	37	1825°
013a	835°	3a	1140°	18	1500°	38	1850°
012a	855°	4a	1160°	19	1520°	39	1880°
011a	880°	5a	1180°	20 [1]	1530°	40	1920°
010a	900°	6a	1200°	26	1580°	41	1960°
09a	920°	7	1230°	27	1610°	42	2000°
08a	940°	8	1250°	28	1630°		

Electrical and optical pyrometers are used in research work in connexion with brickmaking, but are not, so far as the author is aware, employed as an integral part of the ordinary manufacture, as they are delicately constructed, require special skill in use, and for most brickmakers' purposes have no advantage over the Seger cones just mentioned.

For firing continuous kilns it is becoming increasingly common to check the work of the burner by means of a self-recording draught-gauge (fig. 249). This is desirable, because the maintaining of a constant draught is essential to success.

The chart shown in fig. 250 indicates the variations in the

[1] Nos. 21-25 are not now manufactured as their indications are too close together.

draught of a kiln in which the fuel was usually added at intervals of 40 minutes, but by no means regularly. Thus, between 12 and 2 o'clock, over an hour elapsed between the stokings, and between 3 and 4.30 no addition of fuel occurred. The draught varied greatly apart from this, as shown by the irregularities in the line. Such a chart is characteristic of a somewhat careless fireman.

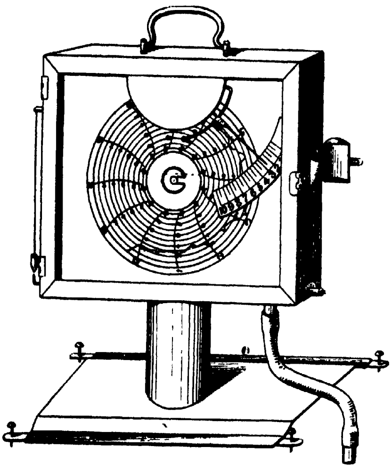


FIG. 249.—Obel recording draught-gauge.

The great variations due to wind naturally lead to serious variations. The actual regulation of the draught, so as to keep it at a constant value, must be done by means of dampers of various patterns, and by seeing that there are no serious leaks in the flues or walls of the kiln. As a check or means of control of these numerous factors the self-recording draught-gauge is invaluable, as will be readily understood from the chart reproduced from the "Tonindustrie Kalender". Against all the usual troubles which occur at night, when the firemen are more or less sleepy, the gauge is a great assistance, as there is no means of falsifying its record short of breaking the instrument itself.

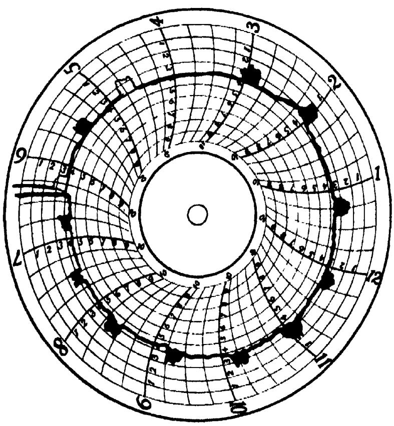


FIG. 250.—Chart of kiln draught.

It is the constant use of an appliance of this kind which en-

ables a burner to appreciate the advantage of mechanical draught produced by the aid of a fan.

It is, occasionally, necessary to work at a lower rate of fire-travel than usual, on account of an insufficient supply of bricks, or because of the works being closed on Sundays and Saturday afternoons. Where the older type of continuous kiln is used it is difficult to damp down for more than twelve hours, but with a modern chamber kiln, in good order, little trouble is experienced. The best way, in each case, is to retard the burning as far as possible by reducing the draught, and feeding at considerably longer intervals. At the same time a flat face of burnt bricks should be exposed in the chamber where drawing is in progress, and this should be papered over completely with the "paper damper" used generally in barrel kilns. This paper damper must be watched, and it can be pierced, if found necessary, near the top to admit some air. As a rule, however, the kiln walls leak sufficiently to let in the air required. This damper will prevent too rapid cooling of the fire, and if the same feed-holes are kept in operation as long as possible the advance of the fire will be very slow. In some modern kilns the paper may be unnecessary, as the dampers will shut off all undesirable heat.

Provided a chamber is kept well closed, the amount of heat lost will not be serious, and the amount of fuel burned will be inconsiderable. It is, however, unwise to leave a chamber in which the firing of the goods is almost complete, without finishing it off properly, the other chambers being held back in such a manner as to prevent any harm occurring to their contents. Thus, it will not, as a rule, seriously damage goods to be kept indefinitely at 150° C. below their finishing point, unless they are glazed, though it is best to keep the temperature as low as possible in goods which cannot be finished at the normal rate.

If kept soaking too near the finishing temperature, there is a tendency for the lower heat to act as the higher temperature does in a shorter time, and finish the goods before the fireman expects it. Hence, it is not always possible to place full reliance on certain forms of heat indicator (such as cones and thermoscopes) when the goods are put under the influence of an abnormally long soaking.

Starting again after a holiday or other stoppage is a difficulty in the older forms of continuous kiln, but in those with grates running from the wicket to the back of the kiln this difficulty is not nearly so noticeable, and in several of the more modern

forms of continuous kiln the simple addition of more coal to that on the grate, or box, is sufficient to restart the burning, especially if hot air is used to aid the combustion, as it is in the best forms of continuous kiln.

The essentials for a kiln in which the output is irregular, or subject to frequent stoppages, are suitable grates or boxes for the fuel, a good system of hot-air supply for the combustion of the fuel, and a simple means of completely isolating each chamber from the rest. These conditions are found in the more recent forms of continuous kilns.

The following "Don'ts for Firemen," published anonymously in the "British Clayworker," contain much sensible advice in brief form:—

"Do not leave your kiln until your mate has arrived at the end of your shift; if he is ill or late the kiln may be spoiled.

"Do not forget to tell your mate exactly how matters stand when he arrives.

"Do not think that a few minutes more or less between the firings will make no difference with a continuous kiln. Punctuality in firing is worth far more than irregularity and skilled 'dodging'.

"Do not think that you can make up with heavy baitings for neglect at an earlier period. Such neglect always leaves its marks for the man who can read them.

"Do not fail to repair any leaks in the kiln walls, or, if they are too much for you to manage, do not omit to inform the manager or master. Much coal and labour can be saved by keeping a kiln free from leaks.

"Do not fail to be informed if damp goods are put into the kiln, so that you may regulate your firing accordingly.

"Do not hurry the first period of firing. Better a slow kiln and good results than a quick fire and a large scrap heap.

"Do not omit to clean out the fires properly. Efficient cleaning improves the goods.

"Do not admit quite cold air to the part of the kiln to be heated. There are many ways of supplying warm or hot air in abundance; use one or more of them. (See "hot air" in Index.)

"Do not let the heat travel irregularly, especially in a continuous kiln.

"Do not omit to give an eye to the setters, so as to ensure their work being properly done. Better a little time spent in this way than hours lost in trying to work a badly-set chamber.

"Do not forget to look frequently at the dampers; neglect of this caution may cause serious trouble.

"Do not use damper-plates which are badly warped or bent. Get them made right or replaced by new ones. Warped dampers waste fuel.

"Do not think that no skill is needed with paper dampers. See that they fit tightly and remain whole until you are ready for them to break or burn.

"Do not dawdle with the full fire; but heat as rapidly as the goods will stand. Slow firing gives dull finishes.

"Do not carry the full fire too near the freshly-set goods in a continuous kiln, and,

"Do not start firing in a chamber until the goods in it have a temperature of at least 120° C.

"Do not forget to test the temperature at the end of the smoking or stoving stage with a thermometer.

"Do not think a poker will do instead of a thermometer for testing for steam in a chamber. 'Poker results' are often misleading.

"Do not fail to test the draught of the kiln frequently. A draught-gauge is often the best aid to efficient firing.

"Do not think that the shrinkage of the goods will always indicate that they are finished. It all depends how dry they were when set.

"Do not finish 'by eye' alone. Use cones, or trials, or both.

"Do not think that all kilns are alike. Study the ones you have to work as carefully as possible.

"Do not cool too rapidly; you may shatter the goods.

"Do not 'soak' your kiln because it was necessary at your last place. With a different clay it may be an absolute injury to the goods.

"Do not hurry off a kiln at the finish, or the goods will be unsound, but

"Do not keep the kiln over-long at a top heat; it may cause a 'crush'.

"Do not forget that the burner's work is about the most important of all, for no matter how skilfully the previous stages may have been carried out a careless burner can spoil the whole."

Cooling.—The average burner believes that bricks should be cooled as slowly as possible, whilst his employer considers that rapid emptying of the chambers is desirable. Consequently, the

one tends to unnecessary delay and the other to undue haste in drawing the kilns. Between these two extremes lies the correct method of cooling.

With single kilns, the cooling is less under control than in a continuous one, though much may be done by judicious alteration of the dampers, particularly when the kilns are enclosed in another building. When the kilns are exposed, the cooling must be slower if there are no facilities for using air at a temperature but slightly lower than that of the cooling goods, and if rapid cooling is attempted without these facilities the bricks will crack and break.

Many tests carried out by the author on a large number of different clays show that the cooling may be relatively rapid until a temperature of about 600° C. is reached; it must be slower for the next 300° C. or thereabouts, and after this it may again become more rapid, providing that cold draughts are avoided. In single kilns it is impossible to cool very rapidly and at the same time avoid cold draughts, and with such kilns it is, therefore, necessary to cool slowly, and whilst no definite rate of cooling can be stated, it is wise to allow the cooling to take the same time as the heating required between the end of the smoking and the finishing of the chamber, omitting any special time allowed for prolonged soaking in order to burn out carbonaceous or other matter, or to completely oxidize the iron.

The best rate of cooling must, however, be determined separately for each kiln; and provided the goods are not damaged, and no serious quantity of heat is lost, the more rapidly the chambers are cooled the better.

With a large continuous kiln much more rapid cooling is possible, as the air employed for this purpose may be used at a temperature but little below that of the bricks, and, consequently, large volumes of air may be employed without in any way damaging the bricks.

To cool bricks rapidly requires a continuous kiln of great length, as at least 60 ft. should form the cooling portion, and for very rapid cooling twice this distance is needed in some cases. The bricks will then cool as steadily as they were heated. One of the most foolish practices in many otherwise well-managed yards is that of having too few chambers in the cooling portion of a continuous kiln when a rapid output is required.

Attempts have been made at various times to hasten the cooling by blowing air into the kilns. These have only been

satisfactory when warm air has been used, and this is commercially unprofitable in most cases.

The ordinary brickmaker who wishes to cool single kilns more rapidly than usual, should make openings near the roof of his kiln and should leave his main dampers fully open. If the kiln has a flash-wall or bags, the fire-boxes may be opened partially, and the damper regulated accordingly so as to prevent too rapid a current of air being drawn through the kiln. Bricks vary so much in their abilities to withstand sudden changes of temperature that each maker must decide, by actual trial, what is the best method of cooling his kilns.

CHAPTER IX.

VITRIFIED BRICKS FOR SPECIAL WORK.

FOR certain engineering work, bricks of exceptional strength are required, and for this purpose those which are more vitrified than ordinary building-bricks are selected. The reason for this is that in a well-vitrified brick the burning has been carried as far as possible, and the particles are bound together with a species of glass into a mass of enormous strength.

The colour of *engineering bricks* is of secondary importance, but great strength and accuracy of shape are essential. In different districts very different kinds of bricks are used for this purpose, a vitrifiable red-burning shale being popular in Yorkshire, a similar buff-burning shale being used in some parts of the Midlands and West, but the most popular engineering bricks are the "blue bricks" made in Staffordshire.

These blue bricks are really slag-coloured, and are made from special clays (locally known as "marls") which occur in great masses in South Staffordshire, particularly in the neighbourhood of Dudley. These clays require the use of powerful machinery as they are difficult to crush, and the kilns must be fired at a high temperature in order that vitrification may be as complete as possible. The "blue" colour is obtained as the result of the reducing conditions in the kilns at the high temperatures used, and under-burned bricks made from the same materials are red in colour. The iron oxide in the clay is reduced to a lower oxide and formed into a silicate, previous to the end of the firing. A similar effect is produced in some German works by the introduction of tar and oil into the kilns when they have reached the maximum temperature and are almost ready for closing.

In making blue bricks from the Staffordshire marls, several superimposed materials are available, as will be seen from a study of a geological survey map of the district, which shows this long bed of "clay" very distinctly. As most of the eight or ten different layers found are of similar composition, they are mixed together

for brickmaking, but it is unwise to use the lowest beds, as they often produce a scum.

The material must usually be obtained by blasting and felling and is taken by wagons (into which the materials are put in the proper proportions) to the crushing plant. Here it passes through several sets of rolls (figs. 46 and 47) and thence into a mixer and pug-mill. Formerly the bricks were moulded by hand, but wire-cutting (pp. 76 and 130) is now the most popular method. For bricks of more than ordinary accuracy repressing (p. 139) is practised. The bricks are dried on heated floors (p. 157) or in tunnel-dryers (p. 161), and are fired in up-draught kilns of rectangular or circular shape.

The use of continuous kilns for blue bricks has only been successful within the last few years, as very high temperatures are required and the conditions of burning are peculiar. With a double-grated chamber-kiln working on the continuous principle (Barnett's patent, p. 300), perfectly satisfactory blue bricks may be obtained, using only about half the amount of fuel ordinarily consumed.

The exact temperature reached in blue-brick burning differs considerably in different works in the same district, but is seldom less than 1200° C.

The atmosphere inside the kiln must be strongly reducing, or alternately oxidizing and reducing, in order to gain the full advantage of the fluxing power of the iron oxide present. With the clays most suited for blue-brick manufacture there is no need for special precautions being taken, providing the kiln is heated steadily and finished at a sufficiently high temperature, and that it does not leak excessively; but with less suitable clays the production of good blue bricks demands the consumption of a large proportion of fuel, and the exercise of considerable skill in the firing.

In each case, very little air is admitted during the last eight or ten hours, the dampers being partially closed during this period. Immediately the firing is completed all openings into the kiln are closed so as to exclude air until the bricks are quite cold, otherwise they will be of a reddish colour.

Some burners throw a little salt into the kiln just before the close of the firing in order to facilitate the vitrification, but this is not to be recommended.

Clinkers and Paving Bricks are vitrified bricks of any colour, their chief characteristic being hardness without brittleness.

They may be made from any material in which the temperature of vitrification and that at which the brick loses its shape are not too close together. The manufacture of such bricks calls for no special description, as the chief precaution to be observed is that the firing must be sufficient to produce the necessary vitrification without making the bricks too brittle or warped.

They are chiefly made from low-grade fire-clays, shales, or other brick-earths naturally rich in alkalies, but occasionally the admixture of a refractory clay with an easily fusible one will give equally good results. It is seldom possible to add a flux (such as Cornish stone) to a refractory clay in order to produce a good vitrified brick, as the particles of added matter are too coarse, Seger having found that, for successful work, the alkalies in the clay must be so finely divided as to be present in the finest particles obtained by washing in a Schone's elutriating apparatus.

The standardization of paving bricks has been carried out far more completely in America than in Europe, the following requirements and tests being in regular use:—

(*a*) The size of the brick is known as "block size," and must not vary more than ⅛ in. in any block. The preferred size is 8½ in. by 3½ by 4 in., exclusive of all lugs or projections; but bricks of other dimensions may be accepted for use provided the depth is 4 in.

(*b*) Projections or lugs are required.

(*c*) The brand or mark of the brick, to identify it by name or otherwise, must be on each brick. No blank bricks are to be used.

(*d*) The shape of the bricks must be uniform and regular, and must not be distorted more than ¼ in., from the straight edge laid in any direction on them. Edges must be rounded. All bricks must be repressed.

(*e*) The material of the bricks must be homogeneous, uniform, free from laminations, cracks and voids, only very minute fire-cracks being allowed. The material must be thoroughly annealed, fused, and vitrified to toughness without excessive brittleness.

(*f*) The abrasion or rattler test must be made in a standard rattler by the method of the National Brick Manufacturer's Association and the American Society of Municipal Improvements. The maximum loss of any one brick shall not exceed 18 per cent of its original dry weight. The average loss of all bricks tested at one time must not exceed 14 per cent. The standard abrasion

machine or rattler is a cylinder of 14 staves or sides, ¼ in. apart, inside diameter 20 in., length 20 in. It has no interior shaft, and revolves at 30 revolutions per minute for one hour. It contains a charge of 300 lb. of foundry iron shot of two standard sizes; and the charge of brick for a test must approximate 1000 cu. in., which is about nine bricks of the block size. Records of each brick in each test must be kept.

(*g*) The modulus of rupture or cross-breaking of any one brick must not be below 2500 lb. The average of all bricks tested must not be below 2700 lb., by the regular formula $M = (3WL) \div (2AD)$ in which $L = 6$ in. between supports, W = breaking pressure, A = area of cross-section at break and D = thickness of brick. The bricks must be tested on the side and the pressure applied half-way between the supports. At least three bricks must be submitted to this test.

(*h*) The absorption of water by any one brick must not be greater than 3 per cent. The average absorption of all bricks tested must not exceed 2 per cent of their dry weight. The absorption tests must be made on either abraded or on broken bricks, by drying them for twelve hours in an oven, then soaking them for twelve hours in water. The increase of weight due to water absorbed, divided by the weight of the dry bricks, gives the percentage of the water absorbed. At least three bricks must be used for this test.

(*i*) The density or specific gravity must be determined exclusive of the porosity of the brick. No bricks must have a density of less than 2·30, and the average density of all bricks tested must not be less than 2·35.

(*j*) The hardness is expressed in terms of Moh's scale for minerals, in which 100 is the diamond. The hardness of any brick must not be less than 60, and the average hardness of bricks tested must not be less than 65 (i.e. between felspar and quartz).

(*k*) The crushing resistance must not be less than 7500 lb. per sq. in. for any brick, and the average resistance to crushing of all bricks tested must not be less than 8500 lb. per sq. in. The crushing tests must be made on about one-sixth middle sections of brick, with pressure applied in the direction of the whole thickness of the brick, which is the least dimension of the brick. At least three bricks must be used for this test.

(*l*) Chemical tests may be made to determine if there are any water-soluble substances, such as free lime, potash, soda, etc., in the bricks; and if more than a trace is present the entire lot of

bricks from which the sample has been taken must be rejected.

There is no immediate prospect of these or any other standards being recognized by the paving brickmakers of this country, as the use of bricks for road-making here is not apparently increasing. In countries such as the United States and Canada, where great extremes of heat and cold are experienced, pavements made of brick possess many advantages over macadam and other well-known materials.

Acid-proof Bricks are used in large quantities in the manufacture of various chemicals. They must be strong and accurate in shape and as resistant as possible to any chemicals with which they may come in contact. Many fire-bricks are sufficiently acid-proof for most purposes, particularly if salt-glazed, but when a superior brick is required a ball- or stoneware-clay must be used. Acid-proof bricks are not usually required to withstand violent changes in temperature, so that they need not be made of clay possessing great heat resistance. The best acid-proof bricks are those containing a considerable proportion of true clay, the exceedingly fine particles of which fill up the voids otherwise present, and the brick is made impervious apart from any vitrification which may have occurred during the firing.

The standard test for determining the value of acid-proof bricks is to ascertain their crushing strength before and after they have been soaked in concentrated sulphuric acid maintained at a temperature of 90° F. for seven days. All the best bricks sold for chemical works at the present time are quite unaffected by this treatment.

CHAPTER X.

FIRE-BRICKS AND BLOCKS.

THE manufacture of fire-bricks and blocks has been carried on for many years in a somewhat rudimentary manner, and it is only recently that the more important firms attempted to improve their product and bring it up to date.

In earlier times fire-bricks and blocks were only required to withstand relatively low temperatures, but, with the increasingly stringent requirements of modern metallurgists and other users of furnaces, it is necessary at the present time to make use of every available assistance which science can render to the fire-brick maker.

Investigations have shown that various users require widely different characteristics in fire-bricks and blocks, and a material which suits one customer well may be entirely unsuitable for another. It is, therefore, necessary to know what characteristics are required before the value of a fire-clay can be stated.

The *materials* from which fire-bricks and blocks are made are of four main classes: (1) fire-clay; (2) rocks consisting of almost pure silica; (3) rocks composed chiefly of silica but containing about 10 per cent of clay and known as "ganister". Artificial imitations of ganister are also used; (4) neutral and basic materials such as chromite and magnesia.

The treatment of the materials depends on their nature, and the three chief processes used must therefore be described:—

Fire-clay bricks are made from various seams of fire-clay found in several parts of the country, the most noted deposits being in West Scotland, Northumberland, Yorkshire, the Midlands (Burton and Ashby-de-la-Zouch), Buckley, Stourbridge, Shropshire, Devonshire, and Wales. The materials from these various sources differ widely in composition and character.

The West Scotland fire-clays (including those of Glenboig) are noted for their unusual heat-resisting power. They require to

be fired at a very high temperature, as otherwise they are soft and weak.

The Northumbrian fire-clays are chiefly found near the Tyne, and are richer in alumina than those of Scotland. Unfortunately, this advantage is more than neutralized in several cases by the presence of an excessive proportion of fluxing material (alkalies and lime) which greatly reduces the heat-resisting power of the bricks. Several seams in Northumberland and Durham are, however, of excellent quality.

The Yorkshire fire-clays are found chiefly near Leeds and Halifax, but the material crops up unexpectedly in several other parts of the county. In South Yorkshire it is associated with ganister (see later). The fire-clays in Yorkshire are peculiarly variable in composition, the alumina varying from 15 to 39 per cent. The clays richest in alumina are found nearer the surface, but are much more tender than the stronger ones found at greater depths.

Taken as a whole, the Yorkshire fire-clays are amongst the most refractory, but they have not hitherto been worked so as to develop this property to the fullest extent, as they are almost invariably under-fired and so shrink in use at abnormally high temperatures.

The Midland fire-clays are more readily vitrified than most others of equal quality, and are therefore in great demand for the manufacture of close-grained bricks and sanitary pipes. They are not usually so resistant to heat as some others, but where other factors (such as the cutting or corrosive action of dust and fire-gases) have to be considered, they are very valuable, and under some conditions prove more durable than more infusible bricks from other districts.

The Stourbridge fire-clays have a world-wide reputation for refractoriness. The composition is remarkably constant, though unexpected variations occur at times. The average proportion of alumina is about 22 per cent—thus corresponding to the Scotch and some Leeds clays—but portions of clay with over 36 per cent of alumina have been found.

The Devonshire fire-clays, like those of the Ashby district, are relatively easily vitrified, but considerable variations in quality exist. The most noted fire-clays in this county are found in the Teign valley, and often contain considerable proportions of under-composed granite. They are, therefore, used for the manufacture of vitrified bricks where the greatest resistance to heat is not re-

quired, but where a brick which will stand what is ordinarily considered to be a high temperature is required.

The Welsh fire-clays in some ways resemble those of Stourbridge but are seldom so pure, and must, therefore, be worked with caution. The best deposits in this district are of first-class quality for refractory work.

The fire-clays are chiefly found associated with the coal measures and millstone grit, and must therefore be obtained by mining. Some brickmakers are working in the "rubbish heaps" of collieries, but the best fire-clays are obtained direct from mines.

The seams vary in thickness, just as do those of coal, but are less uniform than the latter, and it has generally been considered that the only seams which can be worked at a profit are thick ones near the surface or those mined along with coal. Curiously enough the best fire-clay is often raised from pits containing but little or no coal.

The fire-clay should be selected or "picked" before use, so that nodules of pyrites and other unsuitable material may be removed. It should also be allowed to "weather" as the subsequent crushing is made easier thereby, many shales and fire-clays being exceedingly hard when first mined, but becoming soft on exposure. The picked and weathered material is then crushed in an edge-runner mill with either stationary (p. 95) or revolving (p. 183) pans.

For very hard fire-clay shale the stationary pan-mill is the more powerful, but if a preliminary crusher or stone-breaker is used a revolving pan will often give a larger output.

The material is usually passed through a screen having twelve or thirteen holes per running inch, but this somewhat crude method of working is now being replaced in the most progressive works by a double sieve.

Either before or after grinding, the fire-clay is usually mixed with burnt material of a similar nature (termed "grog" or "burnt stuff") in order that a skeleton may be formed which shall hold the brick together during the drying and firing. The use of this grog is often greatly misunderstood, and in some works it is omitted entirely.

The mixed clay and grog are next passed into a pug-mill, usually of the vertical type (fig. 20) where it is mixed with water and converted into a paste. This paste is sometimes stored away in a heap to "sour," but many workers do not appreciate the value of this treatment and so omit it.

The bricks or blocks are moulded by hand by the slop-mould process (p. 51), slight variations occurring in different shops. They are dried on floors heated by steam (p. 158), or flue-gases (p. 159), and are fired in Newcastle or Scotch kilns (p. 255).

The maximum temperature reached in the kilns varies greatly in different yards. In some it is as low as cone 2 (1170° C.) and in others as high as cone 19 (1510° C.) The higher temperatures used are largely the result of modern investigations and research and are not used in the smaller works. About a week is usually occupied in the kiln, but where exceptionally large blocks are made a much longer time (extending in some cases to two months) is considered necessary, as such blocks are extremely sensitive to sudden changes in temperature before they are fired. It will thus be understood that, formerly, the manufacturer of fire-bricks had chiefly to see that his material was right and that the men worked well. A few degrees more or less in the kiln made but little difference, and so long as his goods were saleable, little else mattered.

Within the last five or six years, however, a great change has come over the fire-clay industry. This is due to a variety of causes, the chief of which is the demand for better bricks and blocks from various users. This demand is increasing as progress with high temperature work continues, and the fire-clay worker of the future must use his best endeavours to meet the demand. Fortunately, the cost of building and re-building is so high, compared with the cost of fire-bricks, that a good price can be obtained for a really satisfactory article.

In order to do this it is necessary to know the general direction in which this demand tends to run, and for this purpose the chief characteristics needed in a fire-brick or block must be studied. It is not possible to obtain all these in a single brick, as they are, to some extent, mutually incompatible, but the worker will know which to select from the whole. The chief characteristics required are:—

1. Resistance to high temperature.
2. Resistance to pressure at high temperatures.
3. Non-absorptive power at any temperature.
4. Uniformity in size, shape, and composition.
5. Expansion or contraction in use.
6. Resistance to abrasion by dust, flames, metal, slag, and other materials.

7. Resistance to reduction or oxidization.

8. Resistance to wear and tear and accidental blows.

9. Resistance to sudden changes in temperature.

As already mentioned, it is seldom that all these characteristics can be obtained simultaneously, and a selection must be made for each case.

Resistance to heat is a property possessed by the material itself and is largely dependent upon the purity of the material and upon the proportion of alumina it contains. At the same time, the results of analysis cannot be reliably used to predict the fusing point of a high-class refractory clay, though in connexion with a Ludwig chart analytical results are often valuable in this connexion.

It is a curious fact that whilst mixtures of pure alumina and silica usually melt in proportion to the silica present, a critical composition is reached when such a mixture contains more than 85 per cent silica, and from this point until pure silica is reached the mixture becomes increasingly refractory, though pure silica is more fusible than pure alumina.

Very small quantities of lime, alkalies, titanium and other oxides greatly increase the fusibility of a fire-clay so that what, in other clays, would be considered trifling impurities, are of great importance in fire-brick manufacture.

Resistance to pressure, abrasion, reduction, and wear and tear is obtained by heating to such a temperature that partial vitrification occurs. This is difficult with really high-grade clays on account of the very high temperature required, so that an unusually strong brick is commonly of second quality as regards fusibility. In many cases, however, a strong brick of slightly inferior clay may prove more serviceable than one made from a purer clay which is weaker.

On the other hand, some bricks which are strong when cool, or only moderately heated because of the binding power of the vitrified material they contain, are often very soft and weak at high temperatures when the vitrified matter becomes viscous. When this is the case, such bricks are of little value and should be replaced by those of purer clay burned at a correspondingly higher temperature.

Expansion and contraction in use are reduced to a minimum by firing the bricks at a sufficiently high temperature during the manufacture, though few British firms do this.

Excessive expansion in use may be due to too much free silica in the bricks, a fault which is also responsible for "spalling" or splitting under sudden changes of temperature.

Stated briefly, the most severe requirements for fire-bricks will be met by using as pure a fire-clay as possible containing a high percentage of alumina,[1] providing the sizes of the various particles of raw clay and grog are properly proportioned, and the whole brick is fired at a sufficiently high temperature. Unfortunately, these conditions are far more difficult to attain than appears at first sight. They involve the careful selection and purification of the materials, the correct treatment in the mills, screens, and mixers, and the use in the kilns of a temperature which is far beyond that ordinarily employed for fire-bricks in this country, as, to the best of the author's knowledge, only three firms in Great Britain were firing their fire-clay bricks sufficiently in 1910.

The selection of the materials for a first-class fire-brick is a matter needing great skill and care. Analysis is useful in order to check the use of clay containing an excess of impurity, but quite apart from this much may be done in routine work by careful observation of the appearance, colour, and texture of the materials. Some attempt is made by most fire-brick makers to avoid the use of "post" and other rocky material, but much more careful picking is desirable when bricks of the highest quality are being made.

In selecting clays it is necessary to bear in mind the characteristics required in the bricks and to choose accordingly. This will often result in a number of different clays being mixed instead of a single one being used, as is often the case at present. It is unreasonable to expect that a single clay—with obvious limited properties—can be successfully made into crucibles and furnace-bricks with equal success.

Whatever may have been done in the past the requirements of the present and future are and will be increasingly stringent, and fire-brick makers will find it more and more necessary to mix several clays in order to produce what they require. In some

[1] The use of free alumina or bauxite to increase the percentage of alumina in a clay is not desirable. A mixture of alumina or silica in the proportions in which these materials occur in a pure clay does not behave in the same manner when fired as clay would do.

Hence the use of bauxite and other free alumina as grog, whilst useful in some cases, does not produce a fire-brick of the very highest class.

cases, by supplying a limited market, less complex mixtures of materials may be used.

Hitherto, the usual practice has consisted in crushing the clay or clays until they are sufficiently fine to pass through a coarse sieve, but careful investigation has shown that this is not the best way to work. Particles of true clay are so exceedingly minute that they are too small to be produced by any machinery. Yet it is to these extremely minute particles that clay owes its plasticity and value, and any method of working that does not make use of this fact cannot be considered as satisfactory. To use clay in a coarse state (as is commonly done) is to waste the material and to produce an inferior article.

The broad principle upon which to work in producing refractory goods, such as fire-bricks, is to form a "skeleton" of as great a heat-resisting nature as possible and to bind this, together with other materials also of a refractory nature, into a mass possessing the necessary strength, resistance to abrasion, temperature changes, etc. Sufficient room must be left between the particles to permit them to move freely over each other within certain limits, so that the brick will not be shattered or cracked when exposed to sudden changes of temperature. As it is impossible to allow perfect freedom of movement of the particles, some softer material must be interposed (in the form of clay) so that it may yield slightly but not excessively under pressure. The main portion of the brick must, therefore, be of as porous and open a nature as possible, any undesirable pores being filled later with a binding material.

The nature of these skeleton-forming and binding materials has been studied but slightly, and further investigation is desirable. The following statements may, however, be accepted as substantially correct:—

The "skeleton" or main portion of the brick must be composed of a clay whose chief characteristic is its infusibility. Such clays when made into the form of a Seger cone should not bend when heated to any temperature below that corresponding to Seger cone 35 for the highest grade of fire-bricks, cone 30 for "first-class" fire-bricks, and cone 26 for second quality or "ordinary" fire-bricks. Although no official British standard exists by which the value of fire-clays may be tested, the figures just mentioned are accepted by the chief experts on the subject in this country and by the chief fire-brick makers in Germany.

Provided a clay is sufficiently refractory, its lack of plasticity,

weakness, and durability are relatively unimportant so far as its use as a "skeleton" is concerned. These properties must be conferred by the use of other clays (binding clays).

As the particles of the material forming the "skeleton" are to be bound together by another material—the binding clay—there is no need to use a plastic clay for this skeleton. It is, indeed, a disadvantage to do so, as plastic clays usually shrink considerably in firing—a most undesirable characteristic in this case.

It is, therefore, best to use for the skeleton a clay which is extremely pure and, at the same time, is in relatively coarse particles and of minimum plasticity. Such a material is furnished under the name of "grog," "burnt stuff," or "chammotte," which is obtained by burning a fire-clay of the highest grade obtainable, at a bright red heat, and crushing the product, as will be described later. It has been customary for the terms just mentioned to be applied to damaged fire-clay goods, fire-bricks, etc., which are added to raw fire-clay for various purposes in a more or less haphazard manner. These sources of an inferior "grog" are sufficiently good for ordinary fire-brick manufacture, but they should not be used by the maker of the highest class of bricks. Glazed materials and slag and potsherds must be avoided at all costs.

E. P. Page has shown that if the grog is not more refractory than the clay used to bind its particles together, the brick may crack on account of the strains set up and the amount of vitrification which occurs. The cracking may not occur immediately, but will do so on repeated heating.

Grog should be made of the purest fire-clay procurable which should be fired in such a manner as to avoid "flashing" or overheating. The temperature reached in its manufacture should not exceed 1450° C. (cone 15), but should seldom be less than 1180 (cone 5*a*). The product should be a creamy mass free from whitish portions and from discolorations. It should be moderately hard, but not excessively so, and should be so refractory as not to bend below a temperature corresponding to Seger cone 30 when made into the same shape as a Seger cone. Grog can usually be manufactured by the fire-brick maker, and the necessary precautions as to purity, etc., can be readily observed; if purchased, the grog should be subjected to a series of rigorous tests before acceptance.

Attempts are sometimes made to use a grog of a different

composition to that just mentioned, by substituting silica-rock or bauxite for burned fire-clay. Such materials are useful in the case of ordinary fire-bricks, but should not be used where bricks of the very highest quality are required. Silica is not so refractory as the best fire-clays, and its admixture may easily cause a reduction in the fusing point. The use of bauxite or other forms of free alumina, on the other hand, whilst useful as giving a "skeleton" of great heat-resisting power, requires special care and skill in use, and is apt to be a continual source of trouble. Most specimens of bauxite are so impure as to seriously reduce the value of clays with which they are mixed. The addition of alumina or silica to a clay should, therefore, only be made under the advice of a really reliable expert who appreciates the difficulties which may arise, and who can study the problem in all its bearings. As commonly used, these materials may do more harm than good. (See footnote on p. 378.)

The size of the grog particles to be used in fire-brick manufacture is important, and it is not sufficient to use all that will pass through a sieve of definite mesh. Very fine grog is useless and should be avoided, as by the nature of the case, the spaces between the coarser particles should be filled by a binding material which should consist chiefly of a plastic clay.

It is therefore necessary, in making the highest grades of fire-bricks, to crush the grog and sift it with two screens, rejecting all that passes through the finer mesh, returning the residue on the coarser screen to the mill for further crushing and only using the intermediate portion. The finest "grog" may be conveniently used in place of sand for "dusting" purposes.

The mesh of the grog-screens must depend largely on the fineness and plasticity of the "binding clay" used. A useful sized grog for preliminary work is obtained by passing the material through a wire screen having eight holes per linear inch, and then on to a similar screen with twenty holes per linear inch, rejecting all that passes through this latter screen. Later tests may show that the grog thus obtained contains particles which vary too greatly in size, but this can be easily remedied by the use of finer or coarser screens. In some cases, particularly in South Yorkshire, it is desirable to use three screens and to employ two sizes of grog; but this is a refinement not usually necessary in fire-brick manufacture.

In Germany, many of the best fire-brick makers use two sizes of grog: (*a*) particles between $\frac{1}{8}$ and $\frac{1}{4}$ in. diameter, and (*b*)

particles between $\frac{1}{12}$ and $\frac{1}{80}$ in. diameter, the relative proportions of each of these materials depending upon the characteristics the fire-bricks should possess.

The *binding material* used to give strength and resistance to the "skeleton" must be sufficiently fine to enter between the other particles; it must be sufficiently plastic to hold the whole mass together before firing, and sufficiently vitrifiable to bind the whole brick into a strong mass with the requisite qualities, whilst not being so fusible as to seriously interfere with the heat-resisting power of the brick as a whole. The binding material must not shrink so much in the kiln as to cause deformation or warping of the brick.

Taking all these qualifications into consideration, it is evident that the most suitable binding material will be a refractory clay of moderate but not excessive plasticity. It must not be quite so refractory as the grog, but must still be sufficiently free from fluxing materials to enable the brick to withstand great pressures at a red heat.

A single clay is seldom found which will meet all the requirements of a binding clay, and two or even three clays may be necessary for the highest class of fire-brick. For what are at present generally considered as "best" fire-bricks (but which are far inferior to what can be produced) a single binding clay can usually be employed.

When two or more clays are used as binders the leaner ones should be ground so as to pass through a No. 20 sieve but not through a No. 100, the fatter clays being ground as finely as possible.

If several clays are used the proportion of each must be settled by actual tests.

There are, unfortunately, great difficulties connected with such tests, and the fire-brick maker who has discovered a really successful blend of clays has gained a great advantage over his competitors.

The clays used for binding must be carefully selected, any unsuitable material being picked out, and the whole mass exposed to the weather so as to reduce the labour and cost of crushing.

The fineness to which the binding clay should be crushed depends greatly on its nature. Highly compressed shales need reducing to a fine powder, but some of the less dense clays are so readily disintegrated by water that a comparatively rough crushing is sufficient, the final reduction taking place automatically

during the "souring" process. It is seldom, however, that clay particles larger than $\frac{1}{20}$ in. diameter should be used in fire-brick manufacture, as the coarse particles required are best supplied in the form of grog which cannot become broken up by later treatment, as frequently occurs with coarse particles of clay.

A single screen may be used for the binding clay, as the finer the particles of this material the stronger will be the brick, and in any case clay particles are naturally far smaller than can be obtained by any mechanical process of grinding.

The *grinding* of both clay and grog is best accomplished in edge-runner mills (p. 375) of either the stationary or revolving pan type, the latter being preferable for the clay as it effects a better mixing of the material.

A preliminary crushing between small rolls (p. 86) or in a stone-breaker often effects a saving in power and in the wear and tear of the larger mills, and increases the output by making the supply of material more regular. Edge-runner mills should never be supplied with pieces more than 4 in. diameter if they are to work economically, and the present custom of many fire-brick makers of feeding pieces of all sizes into the mills is against their best interests.

The preliminary crusher should be arranged to deliver the material on to a floor from which it can be readily shovelled into the edge-runner mill. If an automatic feeding device is employed for feeding the latter the preliminary crusher may deliver direct into this machine. (See pp. 181 and 183.)

It is often more economical and facilitates the output if two edge-runner mills are used, both delivering into the same pit. The first receives the material to be crushed and the second the "tailings" from the screen. In this way the harder portions are kept separate, as far as crushing is concerned, and by using mills of the proper sizes the output is greater than if a single (larger) mill is used. It is important that both mills should deliver to the same elevator so that the material may be kept mixed.

Where several clays are used, each should be ground in a separate mill, as this is far more satisfactory than (*a*) mixing the coarse materials and grinding the mixture, or (*b*) cleaning out the mill each time a change of material is made. Grog should never be ground in the same mill as the clay unless second-quality fire-bricks are desired.

The runners should be provided with renewable rims or tires, and should be sufficiently heavy to do their work well.

The grates in edge-runner mills for fire-bricks should have holes or slots not more than ¼ in. in width, and for most purposes ⅛ in. holes are best. The day when lumps of material ½ in. or more in diameter were permissible in fire-bricks of good quality is rapidly passing away, and pieces ¼ in. wide are the largest which are now considered satisfactory, and for first-class work only very few of these are allowed.

Each mill should be "run off" every noon and evening, and any material on the pans should be collected and thrown aside. It will usually be rich in nodules of pyrites and other undesirable impurities in the clay, but should be tested carefully from time to time.

The nature of the screen used is important; piano riddles have not proved successful in grinding fire-clays and grog in many cases, because the material is so hard and sharp that it wedges between the wires and so delivers too coarse a product.

The well-known wire-gauze screen may be employed, or a sloping plate of perforated steel (see "Newaygo" screen, p. 194) may be used. The size of the holes in the latter corresponding to the former must be found by experiment, as they differ with different materials. As a rule a dry fire-clay will behave to such a screen having ⅛ in. holes as it will to a gauze-screen with a $\frac{1}{20}$ in. mesh, but the perforated metal gives a much larger output. (See p. 192).

The crushed materials should be stored in a dry place in bins where they can be kept apart from each other, yet can be readily measured and mixed before being treated with water.

The best method of proportioning and mixing is to employ large boxes on wheels, the size of each box being proportionate to the amount of material to be mixed. Thus if thrice as much clay as grog is used, the box for the clay will have three times the capacity of that used for the grog. Each box is filled up and any excess of material removed by drawing a flat piece of wood, or strike, across the top. It is better to use boxes of the sizes suggested than to have all the same size and use (say) three boxfuls of clay to one boxful of grog, as errors in counting are frequent with the latter method. The boxes may be mounted on cars and should run on a light track. Their contents should be tipped on to a mixing-plate, fixed at a lower level than the bins, a rough mixture made by means of a shovel, and the material then shovelled into the mixing mill, or a mechanical feeder (p. 182) may be employed, and the labour of one man as mixer

be saved. On no account should the material be fed into the mill without a preliminary mixing having been effected, except in those cases where an intermittent solid bottom pan-mill is used.

The mixing of the materials with each other and with water is effected either in (*a*) a pan-mill (p. 95) or edge-runner mill with solid revolving pan into which a charge of material is placed, together with sufficient water, and the two "ground" for about twenty minutes and then taken out, or (*b*) in a pug-mill. The pug-mill is usually of the vertical type (p. 49), but horizontal mixers and pug-mills are equally effective, though they occupy more floor space (pp. 103-109).

Whichever form of mixing plant is used the water should be added gradually and in a series of fine jets or as a spray. It should not be added in a single stream as is so often the case. A couple of level pipes each perforated with $\frac{1}{16}$ in. holes about 1 in. apart forms a good water-distributor, particularly if each pipe delivers on to the edge-runners instead of directly into the pan.

The paste produced should be set aside in heaps about 4 ft. high in order that it may "sour". At one time it was thought that some kind of fermentation or bacteriological action took place and improved the quality of the material, but it is now generally recognized that the effect of any fermentation in this direction is very small, and that what really occurs is a more even distribution of the water throughout the mass by means of capillary attraction and other purely physical forces, this re-distribution being accompanied by a development of the plasticity of the material. Hence, no matter how thorough may be the mixing, this "souring" should never be omitted in the manufacture of the highest grades of fire-bricks.

With some materials the development of the plasticity of the clay is rapid; these may be used after once passing through the pug-mill or pan, but others must usually be mixed again after "souring," a second pug or pan-mill being used. Some fire-brick makers dread "overworking" their clay; this can only occur when the clay is used where grog ought to be employed, and by replacing part of the clay by a suitable grog satisfactory results will be obtained.

The bricks are made from the paste by hand-moulding, using brass or brass-lined moulds for ordinary shapes and zinc-lined ones for shapes which are seldom required. The process is very similar to the slop-method used for building-bricks (p. 50),

though, like the latter, it varies slightly in different works. The bricks are carried off between two pallet-boards by a boy or girl and are set down on a heated floor (p. 157).

Many attempts have been made to use machinery instead of hand-labour, and some amount of success has been attained by the employment of machines imitating hand-moulding (p. 68) and by use of the wire-cutting process (p. 76). The stiff-plastic and semi-plastic methods have not, hitherto, proved successful, and hand-made bricks are still considered to be the best. The great reason for this is the tendency for machines to compress the clay too much. If the paste remains sufficiently soft (as soft as in hand-moulding) it is difficult to keep it of the proper shape during wire-cutting, and the use of a stiffer paste produces a less satisfactory brick. The temptation to secure greater accuracy of shape in the brick by mechanical pressure should, on this account, be avoided, and represses should never be employed for bricks to withstand high temperatures in actual use. For the same reason, machine-pressed bricks which are not sufficiently perfect to be used for glazing are of small value for the highest temperature work; the pressure to which they have been subjected to give them greater accuracy of form so necessary in glazed bricks has reduced their value for furnace-construction. The desirability of accuracy in shape for all fire-bricks must not be overlooked, but it must not be produced by the use of greater pressure than is used in a hand-moulded brick. Even if the method dry-pressing (p. 241) were to become more popular for the manufacture of fire-bricks, the great wear and tear of the dies, due to the large amount of grog necessarily present, would probably rob the process of any saving in manufacture. Yet this is undoubtedly the direction in which to look for cheapened output with superior quality.

Blocks and large pieces of fire-clay are moulded by the same (slop) process, wooden moulds being employed. A portion of the drying floor is cleaned, dusted with clay dust, sand, or fine grog to prevent undue adhesion of the clay, and the wet mould is placed on the floor so prepared. The maker next throws large masses of paste with great force into the mould, and by vigorous "pommelling" with his fist and kneading with his fingers compresses the clay as equally as possible. The mould having been filled, any excess of clay is removed with a strike or wire, and the mould is removed either immediately or after a short time. Some blocks are made in plaster moulds.

The *drying* of fire-bricks offers no special difficulty, providing it is effected carefully, but larger blocks or slabs need much attention or they will crack.

Fire-bricks, slabs, and blocks are usually dried on fire- or steam-heated floors (p. 157), and these are usually satisfactory but slow, particularly with the larger pieces. It is, in fact, not unusual for a large block or slab to remain on a floor for three weeks without any heat being applied to it. Such a method of drying is highly unsatisfactory, and most block manufacturers would find a study of the principles of clay drying well worth while.

One of the secrets of rapid and successful drying consists in not allowing the outside of the brick or block to dry more rapidly than the inside. This accurate regulation of the speeds at which the various portions of a block dry can only be accomplished by proportioning the amount of air in contact with the article, and by ensuring that this air contains just the correct amount of moisture. In using a steam-heated floor, such as is ordinarily employed, such accurate regulation is impossible; it can only be obtained in tunnels to which air is admitted by means of special valves and moved by means of a fan.

By the careful use of small chambers in which moist air is used at various temperatures, the earlier stages of the drying may be considerably shortened without increasing the risks of cracking, but the subject is not sufficiently closely related to brickmaking to be described in further detail in the present book, but see pp. 161-176 and 213-217.

Dipped fire-bricks are used for special purposes, where they are required to possess characteristics incompatible in the brick as a whole, such as maximum heat-resistance combined with entire absence of absorption. They are really a species of glazed brick, but instead of a true glaze are, in part, coated with a non-porous material. This coating is applied in a manner similar to that used in glazing.

Fire-bricks are *set* in the kiln in a manner similar to that used for ordinary bricks, but they should not be placed so close together. Larger blocks must be set near the centre of the kiln, and according to their shape, so as to reduce the risk of twisting as much as possible. A chequer-work arrangement, as in fig. 104, is very popular, the bricks being set on their sides and not flat as shown.

A little grog dust sprinkled between the bricks and blocks

enables them to be separated from each other more readily when the kiln is drawn.

When large blocks have been placed in a kiln special care is needed to keep away draughts and sharp currents of air. A door should, therefore, be provided for the kiln and used.

The *firing* of the bricks is usually carried out in kilns of the Newcastle (p. 255) or round down-draught (p. 248) type, but continuous kilns (p. 263) may be equally well employed if a suitable design is chosen. The Dunnachie kiln (p. 304) has been successfully used for many years for the purpose. The heat required is more and the temperature of finishing is much higher than with ordinary bricks, but in other respects the same methods are used.

The ordinary fire-brick of commerce is seriously under-fired, being seldom heated to more than 1250° C. The result is that it shrinks and becomes loose in use and wears away rapidly, as the wide joints so produced cause an unduly large surface to be exposed.

Zoellner has shown that all clays when heated to temperatures above 1300° C. (cone 10) dissociate and become crystalline, with the formation of silimanite ($Al_2O_3SiO_2$) and a glassy mass richer in silica than true clay. This latter material may be removed by hydrofluoric acid, in which it is soluble. Zoellner states that this "shows the necessity of heating fire-bricks and other refractory goods to a much higher temperature than is customary, as the crystals of silimanite form a felted mass which is harder, more acid proof, and more resistant to sudden changes in temperature than is clay which has not been partially dissociated by firing at a high temperature". Most manufacturers try to avoid crystallization!

For the best grades of fire-brick the finishing temperature should certainly not be less than is sufficient to bend cone 18 (1500° C.), and for somewhat less important bricks a kiln temperature corresponding to at least cone 12 (1350° C.) should be reached. For export, where the requirements are not so stringent, cone 5 may be regarded as indicating the maximum temperature necessary, though harder-fired bricks will suffer less damage in transport, and will be superior in quality.

Fire-bricks are usually more porous than ordinary ones before firing, and the earlier stages of burning may often be passed more rapidly. With large blocks the matter is very different, and the earlier stages are sometimes prolonged to several weeks.

The final heating should be very steady but moderately rapid, and the cooling—whilst rapid at first to carry the goods past the "danger zone" (1100-1200° C.) where, under slow cooling, excessive crystallization may set in—should be steady and somewhat slow in its later stages.

Many fire-brick manufacturers allow the bricks to cool "anyhow," with the result that on passing near the kilns during the evening when all around is quiet, a sound as of repeated pistol shots is heard. These are signs of the production of minute cracks—often too small to be seen—but readily proved to be present by the reduced strength of the bricks as compared with those properly cooled.

If single kilns are used, the desirability of introducing hot air during the cooling should be considered; in continuous kilns the cooling is under much greater control.

Fire-bricks are paricularly sensitive to rain and frost, and must be stored carefully in a dry place, or their strength (as shown by crushing tests) may be reduced to four-fifths its original amount.

In short, the manufacture of the highest grades of fire-bricks is a matter requiring far more study and attention than it generally receives in this country, as modern users of these bricks are working at temperatures undreamed of fifty years ago, and with the tendency to more stringent requirements the difficulty of manufacture will increase.

For the highest grades, price is of small consideration, and the manufacturer who wishes to progress will reap the reward of his experiments in due course. The ultra-conservative manufacturer, on the other hand, may have an uncomfortable time if the proposed "Standardization of Firebricks" comes into force.

Inferior fire-bricks are used for a variety of furnaces, boiler work, etc., where their heat-resisting power is of secondary importance. The manufacture of such bricks is much easier and cheaper than that of fire-bricks of the highest grade, and the material may often be taken direct from the mine, crushed until it has all passed through a screen with ⅛-in. holes, and mixed with water and made up into bricks.

If the clay is very fine, "grog" may be used, but it is not necessary to use high-grade fire-clay for this purpose. Old fire-bricks, silica rocks, or pure sand may be used with complete satisfaction, provided that the particles are of approximately the correct sizes. Such bricks cannot, of course, be used in the most

trying conditions, but they serve a useful purpose in many industries.

In this class of fire-brick the grog is chiefly used to "open up" the material, so that the bricks may be dried more rapidly and with less risk of cracking in the kiln.

It is not used at all for increasing the refractoriness of the material. The addition of such non-plastic material has a noticeable influence on the bricks, as is shown by tests made by F. Kase, who has published the following facts in regard to the use of fine sand as grog:—

The finer the grains of sand added to the clay, the total percentage of sand added being kept constant—

1. The more water will be necessary for mixing.

2. The longer the mixture will take to dry, and the greater the danger of cracking.

3. The contraction on drying and in the kiln will be greater.

4. The porosity of the fired ware will be less.

5. The "speed of absorption" will be less.

6. The crushing strength will be greater.

7. The material will stand sudden changes of temperature less easily.

8. The silica in the clay will combine more readily.

The characteristics of the clay will be altered with varying proportions of sand-grains, all of the same sizes, as follows: The larger the proportion of sand added to the clay—

1. The less the water required in tempering.

2. The more rapid the drying.

3. The less the contraction both in drying and in the kiln.

4. The less the porosity in under-burnt ware, and the greater the porosity by fully fired ware.

5. The greater the "speed of absorption".

6. The less the crushing strength.

7. The greater the refractoriness.

8. The lighter the colour (with a red-burning clay).

9. The better the ware will withstand rapid changes in temperature.

Silica bricks are often regarded as "fire-bricks," though usually the latter term is confined to bricks made of fire-clay. Silica-bricks are not as refractory as bricks made of the best fire-clay, but they are often superior to those made of lower-grade clays or of good clays badly treated in manufacture

The maximum temperature which silica-bricks made of the

purest materials can stand is comparable to cone 34, but most commerical' specimens cannot resist more than corresponds to cone 30. Fire-clays which fuse at a temperature corresponding to cone 36 are commercially obtainable.

Some bricks branded "Dinas" are occasionally offered for sale which are not true Dinas bricks, being made of a material rich in fire-clay, whereas true Dinas bricks are quite destitute of clay. In Germany and Russia the term "Dinas" is applied to all fire-bricks very rich in silica.

The fusibility of silica is greatly reduced by comparatively small proportions of iron oxide, lime, magnesia, and alkalies, and only those materials which contain upwards of 98 per cent of silica should be used.

The chief disadvantages of silica-bricks are their brittleness, and liability to "spall" when exposed to sudden changes of temperature. These defects appear to be a characteristic of the material used, and not to be due to defects in manufacture, though badly fired silica-bricks spall more than others.

Silica-bricks expand when they are heated, and this increase in size continues through several heatings, though the first heating has usually the greatest effect. The total increase is sometimes very large, but is not usually more than 8 per cent. Allowance must be made for it in laying the bricks, and to reduce this, some users insist on being supplied with twice-burned bricks.

The materials used in the manufacture of silica-bricks are sand and silica-rock, a special variety of the latter found in the vale of Neath and known as Dinas rock being highly valued, but other sandstones, when sufficiently pure, are also used.

The rock is crushed between rolls (p. 86) and is afterwards ground in an edge-runner mill (p. 95) with a solid pan, lime and water being added. The lime is used as a flux or binding material, and about one-fiftieth of the weight of the rock is added.

Hence, good silica-bricks contain 97 per cent of silica, 1½ to 2 per cent of lime, and 1½ to 2 per cent of impurities. On heating, the lime combines with the silica, forming a viscous mass, which on cooling binds the particles of the brick together. It is, therefore, necessary that the lime should be equally distributed throughout the mass, and for this purpose an edge-runner mill with solid revolving pan is the most suitable appliance.

The lime is best added in the form of "milk" made by stirring up the lime with water, allowing the coarser particles to settle, and running off the milky liquid through a No. 60 screen

into another tank. The material in the second tank is tested to ascertain the proportion of lime it contains, is stirred up, and a suitable proportion run off into the mixing-pan. Lime-milk varies so in composition that it is essential to test it if the best results are to be obtained.

The testing is not difficult if carried out in the following manner: 50 cc. of the milk of lime is measured off by means of a pipette into a basin or tumbler, a few drops of phenolphthalein solution added, and the mixture stirred vigorously with a glass rod until it is strongly coloured throughout.

"Normal sulphuric acid" (obtainable from most chemists, but not to be confused with concentrated or dilute sulphuric acid) is then added from a burette, drop by drop, with constant stirring, until the colour of the lime liquid is just discharged. Each 1 cc. of the acid corresponds to one eleventh of an ounce (·091 oz.) of lime in each gallon of milk.

Instead of lime, some makers use plaster of Paris, but this is better avoided as the presence of sulphates is sometimes injurious to the brick.

Silica-bricks are usually moulded by hand and are dried on steam-heated floors, and fired in round, down-draught kilns (p. 248) or Newcastle kilns (p. 255). No particular precautions are necessary, as the material being non-plastic can be rapidly fired without much risk of damage.

The finishing temperature of these bricks varies in different districts, but does not usually exceed 1200° C.; much better bricks (with far less tendency to spall and crack) are produced when the finishing temperature is raised to cone 17 (1470° C.).

The cooling of kilns containing silica-bricks requires unusual care, as they are very sensitive to sudden changes in temperature.

A much better quality of silica-brick than that usually made can be obtained by using the process ordinarily employed for *sand-lime* bricks. In this process the materials are mixed together in a semi-dry state and are shaped by powerful presses, such as that shown in fig. 166. They are then "hardened" by exposure in a steaming chamber for about ten hours, whereby a partial combination of the lime and silica takes place, and the bricks can be more readily handled and stacked in the kiln. In the ordinary lime-sand (or sand-lime) bricks more lime is used than is desirable in silica-bricks for refractory work.

Although fire-clay bricks made under pressure are inferior to

those made by the ordinary hand-moulding process, silica-bricks are not so seriously affected, and providing the grading of the particles of silica is properly arranged, the use of presses does not appear to be detrimental.

From experiments now being carried out by the author regarding the sizes of grains in silica-bricks, the same grading as is used for fire-bricks appears to be desirable though not essential. Some separation into "medium" and "very fine" particles appears to be very desirable, though to the best of the author's knowledge no maker of silica bricks at present works with this in view, though several makers of lime-sand bricks are doing it. The experiments not being complete, conclusive suggestions cannot be given, but the results already obtained indicate that about one quarter of the rock or sand and all the lime should be ground in a ball-mill to as fine a flour as possible, and this dust added to the more coarsely ground material previous to mixing the whole with water and shaping into bricks.

Ganister-bricks are another variety of fire-bricks; they are intermediate in character between those made from fire-clay and from silica.

True ganister is a dense siliceous rock containing up to 10 per cent of clay. It is found in various parts of the country, the best deposits being in the neighbourhood of Sheffield, Gartcosh (West Scotland), and Dowlais (Wales). It is a water-deposited mineral, probably derived from granitic rocks in a manner similar to clay, and varies considerably in composition.

The best Yorkshire ganisters contain 95 per cent of silica, of which about 5 per cent is in the form of clay.

Ganister-bricks are made in a manner similar to silica-bricks, but lime is seldom added, as the clay in the ganister acts as a sufficient binder. Indeed, the term "silica-brick" is often applied to bricks made of ganister or to mixtures of silica and clay which are intended to resemble ganister.

In some cases, ganister-bricks must be treated very carefully in drying sheds and in the kilns, just as though they were made of fire-clay, but most ganister-bricks can be made and fired rapidly. They should be heated to a temperature corresponding to cone 16 or 17 and require to be carefully cooled.

Basic bricks are usually made of magnesia or bauxite and are weak in resistance to pressure, but remarkable for their resistance to heat. Bauxite is infusible and magnesia practically so, as it only becomes viscous at about 1950° C.

Bauxite-bricks are made by grinding the material to a moderately fine powder in edge-runner mills (p. 183), mixing it with about one quarter of its weight of clay and a little water in a pug-mill (p. 49), and moulding it by hand by the slop-process, so that the process used is similar to that employed for second-grade fire-bricks. Bauxite-bricks may also be made in a stiff-plastic machine and dried on a steam-heated floor or in any convenient warm place.

The burning presents no special difficulties, except that, as the bricks are weak, they cannot be stacked very high, and must therefore be burned in low kilns or on the top of other bricks in an ordinary kiln. The bricks must be protected from "flashing," and plenty of air must be used in the firing, as otherwise the iron oxide present in the bauxite will be reduced and will lessen the value of the bricks. Bauxite-bricks should be fired at a temperature not less than 1250° C., as a high finishing temperature is desirable, but is difficult to secure without reducing the iron. The shrinkage of bauxite is so great that bricks of this material cannot well be used at higher temperatures than that used in their manufacture.

Magnesia-bricks have come much into prominence during the last few years, though the raw material used in them has to be imported into this country. The manufacture is accompanied by peculiar difficulties if a really strong magnesia-brick is to be made from pure materials.

The materials of which magnesia-bricks are made are (1) caustic magnesia, obtained by burning magnesite at a moderate red heat in kilns similar to those used for lime; and (2) dead burned, or sintered magnesia, obtained by heating caustic magnesia to a still higher temperature. This must contain a small proportion of iron oxide (about 4 per cent) as otherwise the sintering temperature would be too high.

The magnesia is ground to a fine powder in an edge-runner mill, a little water (about 5 per cent) being added so as to form a pasty mass. This is allowed to stand for a few days. Some firms grind the materials separately with crushing rolls and mix them by hand, or in an open mixer, instead of both grinding and mixing in a pan-mill. The pasty mass is formed into bricks by powerful hydraulic presses, a pressure of 300 to 500 atmospheres being necessary. A good press will deliver 2500 bricks per day. The bricks are then carefully and slowly dried in well-ventilated, steam-heated sheds, or in drying tunnels. Great care is needed

in moving the pressed but undried bricks, as they are very sensitive to slight shocks and vibrations.

Magnesia-bricks may be fired in round down-draught kilns of small size, but the temperature to be reached is so high that gas-fired kilns are preferable. In any case the kiln should be lined with magnesia bricks. It is essential that the kilns shall be low (not more than 4 ft. 6 in. high internally) and comparatively small. The finishing temperature should not be less than that corresponding to Seger cone 18, and it is usually better to finish with cone 23. The addition of clay and other binding materials is undesirable, as it makes the bricks less refractory.

Owing to the tenderness of the unfired bricks, a skilled setter should be employed to place them in the kilns, and he should be instructed to bed each brick carefully in magnesia sand. This "sand" must have been freed from dust before use, the most suitable sized grains being $\frac{1}{16}$ in. diameter. Fine dust causes the bricks to adhere to each other during firing.

The bricks, when drawn from the kiln, must be gauged accurately and sorted according to size, so that, in use, they may be laid with the narrowest possible joints.

The chief difficulties in the manufacture of magnesia-bricks are due to irregular shrinkage of the raw material, the great pressure required in shaping, and the high kiln temperature. The first of these is by far the most troublesome, but much can be done by carefully determining the density of the raw material and classifying it accordingly.

Magnesia-bricks possess a remarkable power of resisting the action of slag and limestone, so that their relatively high cost is soon saved when they are used in certain types of metallurgical furnaces. They are, however, very sensitive to the action of silica. Owing to a tendency to expand on repeated heating, they should not be used in arches.

The "mortar" used in laying magnesia-bricks should consist of powdered magnesia mixed with one-ninth of its weight of tar. It must be used hot.

Neutral fire-bricks are usually made of chromite (an ore containing about half its weight of chromium oxide and one-quarter of its weight of iron oxide) and are difficult to prepare, as the material is almost destitute of binding power. It is, therefore, usually mixed with fire-clay or bauxite in such a proportion that the bricks contain one-third of their weight of chromium oxide, or chrome ores containing alumina are used.

These *chrome bricks* are best made by crushing the material to a powder, and compressing it by a powerful press (p. 223-236). The bricks are fired at a temperature corresponding to cone 12 or over.

Briquettes of compressed *graphite* or other form of carbon are occasionally used for high temperature work. They are made by grinding graphite or coke to a powder, mixing it with about 20 per cent of tar, and compressing in hydraulic or other powerful presses.

The manufacture of similar briquettes from low-grade coal is greatly used on the Continent to form fuel, but in Great Britain the price of good coal is not sufficiently high to make briquetting commercially profitable.

CHAPTER XI

GLAZED BRICKS

THERE is a general impression amongst brickmakers that any kind of brick can be glazed, providing that the composition of the glaze is known. This half-truth has been the cause of much trouble and loss of money, because few people have yet realized that unless the brick to which the glaze is to be applied is practically perfect the glazed brick will be a failure. Trifling defects in a facing brick are often overlooked, but even smaller defects in a brick which is afterwards glazed will render attempts to sell it entirely abortive. Thus, a few tiny specks of lime in a facing brick may be passed unnoticed by the purchaser, but, if such a brick be glazed, the glaze will shell off above each lime-speck and the brick will be of no value.

Speaking generally, red-burning clays are very liable to defects which are trifling in themselves, but which render successful glazing impossible, and, whilst a few firms have succeeded in building up a good trade in glazed bricks made of red-burning clay, the majority of those who have attempted to use this material on a large scale have failed to show any profit.

Glazed bricks, are, therefore, chiefly made of fire-clay, the second-grade clays with a fusibility corresponding to cone 26 to 30 being used.

A brick to be suitable for glazing must be regular in shape, exact in size, with clean arrises, and a fine face free from small irregularities or discoloured spots. It must be sufficiently porous to absorb the water in the glaze-slip, and must be refractory enough to keep its shape whilst heated at a temperature which will suit the glaze.

Such bricks are usually made by the plastic process (p. 76) and are repressed before being fired, so as to obtain a good shape and face and to make them accurate in size. Any of the re-presses illustrated on pages 140 to 153 may be used; that by Pullan & Mann (fig. 96) has a special measuring mechanism

which automatically makes all bricks pressed in the same thickness, as any excess of clay is absorbed by making a somewhat shallower frog than usual.

When made of fire-clay, bricks to be glazed are often hand moulded, as are fire-bricks (p. 385), and are repressed when partially dry. Dry-pressed bricks are slowly coming into use for glazing purposes, but they have not proved popular so far, owing to their liability to develop tiny surface cracks which are of little or no importance in unglazed bricks but prevent glaze adhering properly.

Much difference of opinion has been expressed from time to time on the desirability or otherwise of burning bricks before glazing them. It is considered that the cost of burning the bricks is so much wasted money, as they have to be reburned when glazed. Experience shows, however, that if the glaze is applied to unfired ("green") bricks, the damage suffered in handling makes a large proportion of the bricks useless when they come from the kiln. These spoiled, glazed bricks cannot be sold except as rubbish, as it is obvious that they are damaged. If, on the contrary, the bricks are first burned without glaze, any defective ones sorted out may be sold as building bricks of good quality, or even as fire-bricks at a higher price. The bricks selected to be glazed are stronger and less liable to damage, the amount of glaze wasted is reduced, and the number of unsaleable glazed bricks is brought to a minimum. These various savings often combine to make it cheaper to fire bricks twice instead of once.

At the same time, it is often possible with extraordinarily careful handling to glaze the unfired bricks and put them into the kilns in a remarkably perfect condition, and if workpeople who will give sufficient care to the matter can be obtained, it is quite possible (though seldom realized) to obtain a large proportion of excellent glazed bricks with a single firing.

A mistake often made by the purchasers of glaze recipes is to consider that they can buy all the bricks they require from a neighbouring yard. Such people forget that bricks intended for glazing need most careful handling, as when chipped at the edges they are rendered useless. As few bricks which have been carted from one yard to another are not slightly chipped, it is practically impossible to buy bricks for glazing unless the glazer is allowed to work on the same premises as the brickmaker.

The glazed-brick manufacturer cannot be too stringent or careful in the selection of his bricks.

The glazes used for bricks must be sufficiently durable to withstand ordinary climatic changes without "crazing" or forming hair-like cracks. They must be sufficiently hard to withstand accidental blows, and must adhere to the brick so completely that they will not chip, or peel off. Glazes which melt at low temperatures (below 1000° C.) do not usually possess these necessary characteristics when fired on a porous body, but tend to craze or peel. Glazes fired at a higher temperature are therefore employed for glazed bricks, as the higher temperature enables a mixture of material to be used which produces a mass more nearly resembling the brick itself. Low-temperature glazes are frequently termed "soft-fired" or "soft," and high-temperature ones are spoken of as "hard-fired" or "hard"; the terms "hard" and "soft" when applied to glazes have no necessary connexion with the softness or hardness of the glaze.

It is seldom that a glaze can be applied directly to a brick, as the colour of the brick itself will usually spoil the colour of the glaze. It is, therefore, customary to cover the face of the brick with a "body" composed largely of white-burning clay and to apply the glaze to this body.

For dark-coloured glazes, particularly green ones, the glaze may often be applied direct to the brick without any intermediate "body," and the use of a white opaque glaze permits the omission of the intermediate "body" when white bricks are needed. Owing, however, to the difficulties connected in preparing white opaque glazes, it is, at the present time, customary to use a white body and a transparent glaze in the manufacture of white-glazed bricks. Opaque glazes are becoming increasingly popular, and have many advantages in spite of the difficulties involved in preparing them.

The clay being suitable for the purpose of making a clean, well-shaped brick, the most important part of the manufacture is the *pressing*. The presses should be placed conveniently near to the second drying floor, or to the dripping sheds, according as the bricks are burned or glazed in the green state, as a little roughness in handling the unpressed bricks will do no damage, but the pressed bricks must be handled as little as possible and carried as short distances as possible.

Two serious errors arise in pressing, and must be prevented at all costs. The first is due to the use of worn moulds or dies, whereby the bricks are formed with an "arris" or rough edge on them, and a clean edge is then impossible if the arris is not re-

moved. The second is where the press-man fails to clean out the die completely, with the result that succeeding bricks have small pieces of clay forced into their faces and these rise during the dipping and later cause the glaze to peel.

Pressing bricks for glazing is necessarily a slow operation (about four bricks per minute being the maximum), and any attempt to hurry the press-man may result in the loss of several hundred bricks, because these are spoiled by loose arris getting on to the faces of the bricks, or in other ways.

Glazed bricks must be laid with the thinnest possible joints, and, for this reason, must be pressed accurately. Any good press may be used for this purpose, but it is sometimes a convenience to use one in which the die can be drawn out on slides to the front of the press in order to discharge the brick, and enable the die to be cleaned before pressing another brick. When the die is movable in this way, it is much easier for the workman to see that it is properly cleaned and oiled than when a die fixed permanently beneath the plunger is used. It is, however, essential that the slides on which the die moves are kept perfectly clean, or the male part of the die will not fit accurately into the other portion and the die will be damaged.

Bricks which are glazed previous to burning require to be set in the kilns with the greatest care to prevent chipping, and the temperature throughout the kiln must be as even as possible or the bricks will be unevenly glazed later. Bricks to be glazed in the green state are often first "clapped" with a flat wooden blade to close up the face, but with a good press and careful man this operation is not necessary.

The bricks to be dipped are placed on a large off-bearing barrow with ample springs to prevent undue vibration, and are taken to the dipper, who has a small wagon to carry his tub of slip.

If the bricks are to be dipped before firing they are placed directly they come from the press on to the barrow already mentioned, a sufficient number of these barrows being provided to allow the bricks to dry somewhat after they have been pressed. This is better than placing the bricks on the floor as they come from the press, as the double handling thus necessary is certain to damage them, and the cost of a few additional barrows is not usually prohibitive.

The barrows with the bricks on them may be run into a warm shed so as to allow the bricks to stiffen and dry sufficiently with-

in two or three hours, or they may be left overnight, bricks pressed one day being dipped on the next. The bricks must not be so dry as to show a lighter colour at the edges. Some firms dip the bricks after they have been dried "white hard," but this is seldom satisfactory as the sudden soaking of the dried face often cracks it.

When fired bricks are to be dipped they should be sorted at the kilns, and good bricks placed on the barrows described and taken to the dipping shop.

The dipping shed is provided with rows of temporary shelves, and the man places each brick on one of these shelves as soon as he has dipped it. As already mentioned, it is usually necessary to cover the face of the bricks with "body" before applying the glaze, this process being commonly known as "body-dipping" or "bodying".

The process of "body-dipping" varies somewhat in different localities, but the following description of the method used by the author and many others can be relied upon as being satisfactory. It requires the services of a man and a big boy, an extra lad being advisable when special bricks are being treated.

The first lad (termed the "brusher") is provided with a basin of "first dip" (see later) into which he dips a broad brush with soft bristles about 2 in. in length, and by lightly passing the brush over each of the bricks on the barrow, a uniform coating of "dip" is applied to each. It may, sometimes, be necessary to go over the edges of the bricks a second time, any surplus material being removed by the brush at the same time. It is necessary that this first coating should be as even as possible, and that it should extend slightly over the edges of the face of the brick.

After each brick has been "brushed" in this way, it is "dipped" into a tub of "body" by the man, being immersed sufficiently to cover the face of the brick and but little more. This dipping requires some amount of skill in order to get satisfactory results and to produce an even coating free from streaks. The bricks should be taken up by both hands, held with the face downwards at a slight angle, and in this position should be dipped into the body with a single, sweeping motion. The movement of the brick in the liquid should be very slight, as a long sweep is liable to cause streaks. The correct movement is obtained when the end of the brick which first enters the liquid emerges at not more than a foot from the place where it enters,

though for some clays even this sweep is a couple of inches too long. The dipped brick is then placed on a shelf to dry.

Bricks which have two faces dipped require even more skill, but the process is the same, the only difference being that a shelf narrower than the brick must be used, so that the glazed portion does not come into contact with it during the drying. Sometimes the bricks are dipped twice in the body after an interval of a couple of hours, but with a good body this is seldom necessary.

The dipping shed should be kept moderately warm (65° F.), but must not be so hot as to cause the body or glaze to peel off. The heat may most conveniently be supplied by steam-pipes about 1 in. diameter near the floor and below the shelves on which the dipped bricks are placed.

Some firms prefer to burn the brick after it has been dipped in the body, but this is not advisable as any slight variation in the heat will prevent the bricks glazing evenly, and discoloured bricks are more frequent than when the bricks are finished before firing.

The *glaze* is applied by dipping in precisely the same manner as the body, but it is usual to let the other end of the brick first enter the glaze.

Most unfired bricks are dipped in glaze within two hours or so of their being "bodied," but the interval between the operations depends upon the brick. The glaze may usually be applied as soon as the body has become dull in appearance and no longer appears to be wet, although it is really so. Fired bricks are ready for glazing within a few minutes after being dipped in the body.

Any surplus glaze is removed (after drying) by means of a fine wire brush, or a sharp knife. The bricks are then ready for the kiln.

The materials used in the preparation of glazed bricks are very numerous, and would require a large volume to describe them fully. For temperatures near 1000° C. they are similar to those used by potters, but for the higher temperatures less fusible glazes are employed, and these are usually composed of felspar, Cornwall stone, flint, and whiting, the corresponding bodies being composed of china clay, ball clay, Cornwall stone, and flint, a little of the brick clay being often used in the "first dip".

Other materials such as barytes, zinc oxide, soda, and plaster of Paris may be added at the discretion of the glaze maker, and the materials must, in some cases, be fritted into a kind of glass and ground before use.

Lead compounds are seldom necessary in hand-fired glazes, and their use should be avoided whenever possible for several reasons.

Coloured glazes are usually made by adding 1 to 5 per cent of one or more of the following metallic oxides to either the body or glaze :—

For *whites*—Arsenic, oxide of tin, tin ashes, oxide of bismuth.

For *browns*—Iron and manganese oxides, coloured clays (siennas and ochres) and umber.

For *yellows*—Titanium, antimony, and iron oxides, lead chromate, and (for orange yellows) uranium oxides.

For *reds*—Ferric oxide, or red copper oxide, or gold under strong reducing conditions.

For *pinks*—Chromium and tin oxides mixed.

For *blues*—Cobalt oxide or phosphate, with or without opacity-producing materials like zinc-oxide.

For *greens*—Chrome oxides, bichromate, copper oxide, cobalt oxide, and yellow clays.

For *blacks*—cobalt and manganese or iron chromate (mixed). A perfect black glaze is unknown.

For *gold*—The metal gold is applied in various forms, but can only be used at very low temperatures.

For *silver*—platinum and some of its compounds.

These materials may be purchased from dealers in potter's materials in the form of "chemicals" or as prepared glazes, bodies, or colours which only require to be mixed with water to make them ready for use on certain clays, though, usually, the composition of bodies and glazes must be altered to suit the particular bricks to be used, so that no general recipe is possible for all cases. The following recipes are, however, given here as indicating the general type of body and glaze which (after adaptation) will be found most suitable for general work :—

FIRST DIP.

China clay	70 lb.
Ball clay	15 lb.
Cornwall stone	10 lb.
Flint	5 lb.
Water, about	10 gals.

Part of the clay may be replaced by the clay of which the bricks are made, but this is not usually desirable, and in the case

of some fire-clays is impracticable on account of the shale-oil they contain.

The amount of water depends largely on the nature of the bricks, and may be as low as 8 or as high as 15 gallons.

The materials should be weighed out accurately, placed in a clean tub, stirred up well and passed through a No. 80 sieve, any material remaining on the sieve being thrown away.

Some workers prefer to use a "first dip" made by adding more water to the ordinary body; where this can be done it saves the trouble of making a special mixture.

WHITE BODY.

China clay	60 lb.
Ball clay	10 lb.
Cornwall stone	20 lb.
Flint	10 lb.
Water, about	10 gals.

These materials should be thoroughly mixed together—a mechanical blunger being used when the quantities to be mixed at a time are sufficiently large—and passed through a No. 60 or 80 sieve. If a blunger is used, the ball clay, flint, and water should be added together, the remaining materials being added when the former have been well mixed. The blunger should be emptied and cleaned out as soon as the paddles have been stopped, or trouble may occur with the materials setting hard.

COLOURLESS GLAZE (CONE 8).

Felspar	20 lb.
Cornwall stone	60 lb.
Flint	5 lb.
Whiting	15 lb.
Water, about	10 gals.

This is prepared in a similar manner to the body. It may have 5 per cent of ball clay or 3 per cent of barytes in place of 5 per cent of the stone. It is better than a purely felspathic glaze, as, being more adhesive, it is less liable to be chipped or to fall off.

Majolica glazes are used for all those clays and colours which cannot be produced at higher temperatures. The bricks must, with majolica glazes, be fired in muffle kilns, and must have been fired before being glazed.

The glaze (usually opaque) is applied by dipping in the manner already described, it being used direct or preferably on a body.

Owing to the low temperature in the glaze kiln the glazes must usually have been fritted before use, or some portion of them must have been submitted to this process.

A typical *fritt* for glazed bricks is composed of red lead, Cornwall stone, borax and soda, with china or ball clay, the proportions varying with the temperature to be reached. Owing to the trouble of preparation, brickmakers usually buy their fritts and colours in such a state that they only need mixing to be ready for use. The larger works employ men who have made a special study of majolica glazes—a subject requiring almost a life's work before perfection can be reached.

The raw materials, as well as the body or glaze slips, must be stored in a clean dry place, which is cool in summer and not cold enough for the slips to freeze in winter. The roof or ceiling must be of such a nature that nothing will drop from it into the slips, and these slips should be kept covered.

Large wooden bins are most suitable for the material. The slips are best kept in glazed cisterns or tanks, set about 3 ft. above the ground-level and fitted with an outlet in the bottom. They should not be too deep for a man to be able to stir their contents easily with the aid of a bat about 2 ft. 6 in. long. Before withdrawing any slip, the liquid must be thoroughly stirred up so that no deposit remains on the bottom.

The slip should be taken to the dipping sheds in glazed earthenware bowls. These can be obtained cheaply, and are far less liable to discolour the bricks than are cans made of zinc or galvanized iron. Iron and brass cans must on no account be used, and enamelled iron is also unsatisfactory.

During the dipping, the glaze and body must be kept in constant motion, and should be frequently passed through a No. 80 sieve to remove foreign particles and to aid in the mixing.

The *setting* and *firing* of the glazed goods are matters requiring great care. The bricks must be placed in such a manner that they do not run any risk of chipping, nor of being discoloured or otherwise damaged by the flame. One satisfactory method of setting glazed bricks is shown on p. 336, though some firms have found continuous (chamber) kilns excellent and economical. Muffle kilns are not necessary if the bricks are placed properly.

Coloured glazed bricks must be kept apart from each other

and from white bricks, as a certain amount of "volatilization" of colour always occurs.

The glazed faces of bricks must also face other glazed faces, or otherwise they will be dulled.

The manner of heating will depend on whether the bricks have been fired before being glazed. If not, they must be heated as cautiously and steadily as possible, all the precautions mentioned in section on burning (p. 337 to 367), being observed. When the bricks have reached a bright red heat and are fully oxidized, the heating should be continued somewhat more quickly than when unglazed bricks are fired, as prolonged heating tends to dull the glaze.

The "finishing point" of the kiln is ascertained by drawing out glazed test-pieces (fig. 251) and by examining these; a fairly accurate idea of the temperature is also obtainable by the use of Seger cones. The full temperature required having been reached, the fires are poked up, sufficient air being admitted to let them die down rapidly (to prevent overheating) and the openings in the kiln are then all closed and made air-tight with clay paste.

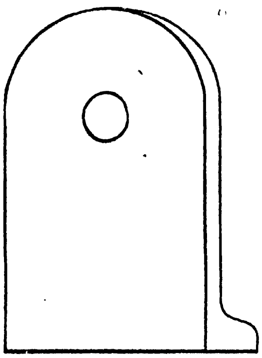


FIG. 251.—Glazed trial-piece.

Kilns containing glazed bricks should be cooled fairly rapidly at first—until the glaze is too cool to devitrify or crystallize—but as soon as they have reached a temperature at which this cannot occur, usually of 900° C., they should be cooled much more slowly.

When the glaze is applied to bricks which have been fired previously, the heating of the kiln may be fairly rapid, but the cooling must be cautiously carried out.

Salt-glazed bricks are in great demand where a cheap but reliable glazed surface is required. Owing to the special manner in which the glaze is formed, it is less liable to defects than ordinary glazed bricks. Water and frost do not affect them in any way. There is a greater demand for light glazed bricks than dark ones. Unfortunately the number of colours available is very limited and white salt-glazed bricks are exceedingly difficult to produce.

Ordinary salt-glazing produces a dark brown glaze (similar to that on drain pipes), but many makers "improve" upon this by first dipping the bricks in a body.

Salt-glazing differs from other methods of glazing in that no glaze is applied direct to the bricks. The bricks are placed in a down-draught kiln and, when sufficiently heated, salt is thrown into the fire-holes and automatically glazes the exposed portions of the bricks.

In simple glazing with salt, the glaze is really formed from part of the salt combining with part of the clay, so that the glaze is necessarily far more adhesive than when all the constituents of the glaze are mixed together and applied in the form of a slip or spray. For many years the composition of the salt-glaze produced on fire-clay was unknown, but Maeckler has investigated the subject very thoroughly and his conclusion that it has a composition corresponding to 20 per cent alumina, 54 per cent silica, and 26 per cent soda and other oxides is now accepted, though the reactions which result in its formation have not been fully explained.

All clays are not suitable for glazing with salt, as it is found that a certain temperature (corresponding to cone 2 but more usually cone 7) is essential for the full development of the glaze, and that the proportion of alumina and silica must be within comparatively narrow limits. L. E. Barringer has shown that the most suitable clays are those containing about 63 per cent silica and 23 per cent alumina, but provided there is not less than 3 lb. or more than 8 lb. of silica to each lb. of alumina in the clay a good glaze may be obtained. Some clays outside these limits can be salt-glazed, but will not give really good results. The state in which the silica is present does not appear to be important, and some clays which, alone, cannot be salt-glazed will give excellent results when mixed with very fine sand, but coarse or medium sand cannot be used for this purpose.

The best results are obtained with clays which begin to vitrify at the temperature at which the salt is added, but which do not lose their shape until a far higher temperature is reached.

For this reason, some firms have obtained very excellent results by the use of ball clays to which sufficient sand or grog (non-plastic material, see p. 18) has been added to reduce the otherwise excessive shrinkage, or by adding some ball-clay to a fire-clay, shale, or other lean clay. Occasionally, a mixture of several clays and grog is employed, the object being to form a "skele-

ton" of lean clay or grog, and to use the fine clay to bind the other particles together and to help the vitrification.

Bricks for salt-glazing can be made by any of the processes already described, but they should be pressed (p. 139) or repressed so as to give them a sharp, clean-cut appearance. The methods used for the manufacture of glazed bricks (p. 397) should therefore be used, but the bricks, instead of being "dipped" when partially dried, are dried completely and then taken to the kiln.

Bricks made from a ball-clay mixture must not be permitted to dry too quickly; if they are forced in drying they will be certain to crack. Two or four days is the average time taken to dry such bricks after being pressed, before they are in a condition suitable for placing in the kiln. If drying space is limited, the bricks can be stacked in rows to dry two days after being pressed, and the space thus vacated may be refilled with fresh bricks.

The bricks must be thoroughly dry throughout before being set in the kiln, otherwise the steam contained in them will cause them to crack.

A "salt dip" or coating for using upon the brick is often necessary to give the surface of the bricks a uniform, smooth surface, which will assist the salt to produce a bright, good-coloured glaze. This salt-dip, or body, is composed chiefly of washed clay (passed through a No. 60 sieve), and it is best to use the same clay for the dip as is used for making the bricks, providing that the clay contains a very small percentage of impurities.

If the clay contains much iron sulphide it is very unsuitable for use as a body-dip, because the iron will cause the surface of the bricks to contain rough, black specks resembling small cinders, and the bricks will not be suitable for good work.

When the clay used for the dip does not produce a good, deep-coloured glaze, it should have mixed into it a small quantity of English or French ochre, or if one sort does not furnish the desired tint, a small proportion of each ochre may do so. When using the ochres great care must be taken that they are thoroughly mixed with the clay, or dip, so that the colour will be uniform on all the bricks. If too much colouring matter is employed it will destroy the soundness of the dip, so that care should be taken to use only as small a quantity of colouring matter as will give the desired shade. In all cases the dip must have a shrinkage equal to that of the brick.

In cases where the bricks are fired to a temperature of 1210° to 1230° C. (indicated by Seger cones Nos. 4 and 5 respectively)

it will be advisable to use a dip composed of good fire-clay and ball clay; a few trials of different proportions will soon determine the quantity of each required for a dip which will adhere well to the bricks. All the materials used for dips should be thoroughly soaked in an equal weight of water (1 gal. to every 10 lb. of clay) before being sifted, and if they are soaking for two or three months they will work all the better. No dip should be used a few hours only after it is wetted, as small air bubbles will come out on the surface and cause small holes or "pinholes". After the dip has been sufficiently soaked it is sifted twice through a No. 30 or 40 mesh sieve.

The dip should be used as thin as is consistent with a perfectly sound surface; the thicker the dip the greater its chance of peeling off or becoming otherwise unsound upon the brick's face. As a rule, five gallons of dip are sufficient to coat about 1000 bricks on one side.

The kilns used in salt-glazing may be single or continuous (chamber) kilns, though there are disadvantages in the latter unless they are used exclusively for salt glazing. In most work it is, therefore, better to use separate down-draught kilns (p. 248) with a perforated or false bottom. There must be ample grate area in the fire-boxes, and the generally accepted rule amongst the builders of salt-glazed kilns—viz., 6 sq. ft. kiln area for each fire-box—is generally satisfactory.

As the damper in the main flue of the kiln is of great importance in salt-glazing, care should be taken that it fits well and is kept in good order. The brickwork must be tight, as a good, sharp draught is needed during some parts of the firing.

The goods are placed so that there is ample room for the salt to reach the faces to be glazed, but apart from this they are set just as if they were ordinary glazed bricks.

To some extent the method of setting depends upon the number of headers and stretchers required to be set.

If 25 per cent of headers are required, the bricks may be set in the following manner: lay a straight edge on the floor at the back of the kiln and set the shortest row of bricks from screen wall to wall, beginning the row with headers. Three rows of headers are next set on edge end towards, and upon the top row of headers the stretchers are set end downwards, face upwards, in a double row back to back, so that the faces of stretchers and headers stand perfectly upright and level. The stretchers should be up four rows high, breaking joint in each row, so that the walls

will be firm and the bricks prevented from tipping during the burning.

Upon this row of stretchers, headers are again laid end outwards, to form a tie to the double wall of stretchers. Every two rows should be tied together with burnt bricks to keep the walls erect. Upon the headers thus set, bull-nose, double stretchers, and other bricks having two or more slyied faces are set up in 9 in. columns leaving a space of 2 in. between each. These are stacked up about ten to fifteen bricks high according to the strength of the clay used, so that the bottom bricks will be strong enough to carry the weight of the others set upon them. When the kiln has been filled, the wicket is built up smeared over with clay paste so that when this is dry the kiln is ready for lighting.

The firing must be steady. When a good red heat has been reached it should be fairly rapid, a good "body of heat" being reached before the salt is added. This is necessary, because the decomposition of the salt is accompanied by a sudden drop in the temperature of the kiln (sometimes as much as 300° C.), and if the bricks are not hot enough the glaze will be dull and scummed.

It is possible to glaze with salt when the temperature is as low as cone 1, but the bricks produced are seldom of first-class quality, and it is far better not to add the salt before cone 7 has been bent over in the cooler parts of the kiln.

As cones are useless when salt is present, many burners dispense with them and heat the kiln until vitrification sets in before salting and the goods have a slight gloss or "flash" on the surface. Some fire-clays give no indication of this kind and cones are then necessary for reliable work.

The working of the kiln when salting varies with different men, but the usual and best plan is to get the fires clear and free from smoke—the bricks being at the right temperature as already indicated—and then to drop the damper to within a few inches of its lowest point. A shovelful of salt is next put deep into each fire-hole in turn and the hole closed with slabs or doors.

After a quarter of an hour or rather longer, the damper is raised and the fires fed with coal, the object being to raise the temperature of the kiln to what it was before salting. When this temperature has been reached the damper is again lowered and another shovelful of salt is placed in each fire-hole, as before. A final firing (with the damper raised) will usually complete the glazing, but this should be confirmed by drawing trials (fig. 251)

which will show whether the glaze is sufficiently thick and glossy.

It is wise to draw trials before adding the second batch of salt, as occasionally the temperature falls more than is expected and a longer period of firing is then necessary. In any case it is useless adding more salt until the bricks are hot enough to decompose it.

Some men habitually add salt three times, but this is seldom necessary, and the use of trials drawn after each firing will show whether a third dose of salt is desirable. Most fire-clays require 10 oz. to 20 oz. of salt per cubic foot capacity of the kiln. The salt may be damped if necessary, but the moisture in the coal is usually sufficient to provide all that is needed.

The colour of the glazed bricks will depend on the clay of which they are made, or the "dip" if any is used, and also on the extent to which the kiln damper is kept open. A partly closed damper will introduce reducing conditions during the firing and will cause the glaze to darken. Light-coloured glazes need plenty of air and a widely opened damper. The ordinary colours are yellow to dark red-brown, or occasionally a brownish black, but if a "body" is applied, the colour produced may be blue, brown, yellow, or green according to the oxides present in the body-slip. In such cases, the damper must be kept fully open and the fires very clear.

The kiln must be cooled fairly quickly until the goods are at a dark-red heat, but the elaborate precautions taken by some burners are seldom needed. The fires should be kept clear by frequent and light stoking, so that when the kiln is finished they may be allowed to die down without any danger of developing "sulphur". As soon as the fires are sufficiently cooled, the fire-holes may be stopped up with slabs and made tight with clay-paste.

"Scummed bricks" are due to insufficient firing before or after adding the salt, and can usually be cured by re-firing at a higher temperature.

Rough and blistered bricks are due to over-heating the clay, especially with insufficient air. This causes it to swell and blister. The defect is caused before salt is put into the kiln, but is more readily observed when the bricks are glazed. The remedy is to fire more slowly at a dark-red heat, with an ample supply of air, until all the carbon has disappeared, or to use a more refractory clay.

CHAPTER XII

PERFORATED, RADIAL AND HOLLOW BRICKS AND BLOCKS. PARTITION BLOCKS AND FIRE-PROOF FLOORING.

THE manufacture of hollow or perforated bricks and blocks has increased greatly during the last few years, particularly in the manufacture of partition-walls and flooring of a fire-proof nature for modern building. The manufacture of hollow blocks is really very old, but it was only during the last century that extended use was made of this valuable form of architectural work.

"Perforated bricks" have a series of small holes transversely through them, these holes being not more than ⅜ in. diameter.

"Hollow blocks" have much larger holes running through them. The hollows or "tubes" may run either lengthwise or transversely through the blocks, the former being the more usual

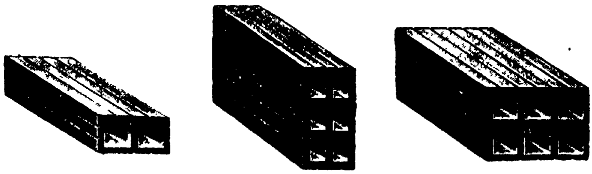


FIG. 252.—Hollow blocks.

(figs. 252 and 253), and the exterior of the blocks can be of any shape which can be produced from a mouthpiece connected to a pug-mill or similar press. Thus, for fire-proof flooring the blocks are often somewhat bent, so that when put together they have a distinct "camber." Such blocks are in great demand in connexion with various systems of "reinforcing".

The shape of the hollows is a matter of some importance to the block manufacture, as it is far easier to produce circular or elliptical ones than those of square or angular section, as the latter require more power and the cores must be frequently renewed as they wear rapidly. The shape of the ends of these cores determines that of the hollows, but the cores must usually taper

towards the back of the mouthpiece (fig. 254) in order that the

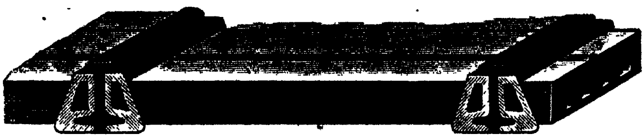


FIG. 253.—Hollow fire-proof flooring.

clay may not be strained and cracked as it issues from the machine.

Hollow blocks with closed ends may be made by using hollow cores which can be closed intermittently by mechanically operated shutters. The resulting clay-band then consists of a series of alternating solid and hollow portions, the lengths of each depending on the time the shutters remain closed. The clay-band is then cut, by wires, into separate blocks.

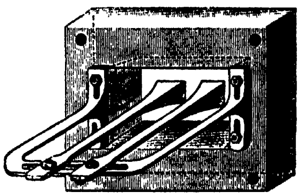


FIG. 254.—Back of mouthpiece.

Radial bricks are used for chimney construction and are frequently perforated. They are best made thicker than ordinary bricks, the cutting wires being placed $3\frac{1}{2}$ in. apart, as this saves labour in bricklaying and, by reducing the number of joints, it increases the strength of the chimney. Perforated bricks are preferable to solid ones in chimney building, as the workman can place his fingers in the perforations if these are large, and can thus use wider bricks than could otherwise be employed. Hollow and perforated bricks are also poorer conductors of heat than are solid ones, and this is a further advantage.

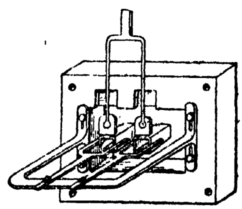


FIG. 254*a*.—"Cella" die for hollow blocks.

For each change in the diameter of the chimney a fresh mouthpiece will be required, as the fitting of temporary liners has seldom proved satisfactory.

Both perforated and hollow bricks are valued on account of their lightness, but to a small extent they are made in order to

save material. Their lightness compared with solid bricks effects a great saving in freightage charges, and enables floors, ceilings, and partition walls to be erected in places where solid blocks would be too heavy. Some Continental brickmakers prefer to use perforated bricks for glazing and facing work, because, unlike solid bricks, they are not lifted by hand from the press, but are received on a "fork," the prongs of which engage in the perforation, so that there is little or no danger of the faces of the bricks being damaged.

From a technical point of view, hollow bricks have the advantage of drying more rapidly and thoroughly and of requiring less fuel for burning. On the other hand, trifling defects in a solid brick become more easily visible in a hollow one, and errors in the adjustment of a machine which would pass unnoticed when solid bricks are being made, require prompt attention when hollow bricks are produced.

Perforated bricks are usually made by fixing bars the size of the perforations in the mouthpiece of the pug-mill, so as to form a series of cores, or in the lower part of the die when the semi-dry or dry-dust process is used.

Hollow blocks are frequently made from a mixture of clay and sawdust; the latter burns out in the kiln and produces a much lighter material than would otherwise be the case. This material has also an advantage in that it enables nails and screws to be driven into it, a property much appreciated by housewives. The proportion of sawdust which may be used depends to some extent on the plasticity of the clay employed, but it seldom exceeds one-quarter of the weight of clay.

Coal and peat are sometimes used instead of sawdust, but the former is not to be recommended as it is liable to cause over-heating of the material in the kilns.

Hollow bricks are made almost exclusively by the plastic or stiff-plastic process in a pug-mill with mouthpiece (p. 108) when large numbers are needed. When only a few are required, and for ornamental patterns, plaster moulds are used.

The clay is mixed into a paste in a pug-mill and forced through a mouthpiece (p. 113) provided with one or more cores. The clay-band produced is then cut into suitable lengths on a cutting table, and these are set on a warm floor or on shelves to dry.

In making hollow blocks, the clay must be very thoroughly mixed, as if of uneven composition the paste will crack or tear on issuing from the mouthpiece or on drying. For this reason

they are frequently made in a machine separated from the pug-mill or mixer, the clay being forced through the mouthpiece by means of a plunger.

For some of the larger blocks plunger machines or "stupids" are employed. These are of various types, but, unlike the ordinary pug-mill with a mouthpiece, they do not work continuously, though by using two plungers an almost continuous output can be obtained. A typical machine of this kind is shown in fig. 255. It consists of a case or charging box containing the clay paste, and a plunger which is forced forward by steam pressure which acts directly on the end of it, the steam entering through a 2 in. pipe into the cylinder at one end of the machine, the amount of steam admitted being controlled by a hand lever at the mouthpiece end. As the plunger travels forward under the pressure of the steam it pushes the clay before it and forces it through the mouthpiece. The pressure exerted may be much greater than that obtained with an auger machine or pug-mill, and as there is no possibility of the clay working backwards (as when knives are used) such a machine is well adapted for use where very large hollow blocks are made. Many brickmakers find such a machine useful for all kinds of "odd work" such as copings, invert blocks, and various special or ornamental bricks, drain-pipes, etc.

The machine shown in fig. 256 is driven by hand instead of steam power, and is, therefore, convenient in many works. The lid of the clay box is fitted with weights and chains so that it can be readily lifted, and the fastenings are simple and strong. A cutting-table is placed in front of the mouthpiece of the machine, when in use, but is not shown in the illustration.

Suggestions regarding the construction and use of mouthpieces will be found in the section on the wire-cut process (pp. 108, 129), but the insertion of one or more metal cores (to form the hollow) makes additional precautions necessary.

In the first place, the cores must be exactly central or the walls will be cracked or torn as the clay issues from the machine, and they must be tapered away from the front of the mouthpiece so that the clay may become steadily more compressed in its passage through the mouthpiece. In order that these conditions may be fulfilled the cores must be attached to a metal "bow" or frame at the back of the mouthpiece, this frame being slotted so that the cores may be moved vertically and horizontally as shown in fig. 254, which shows two cores fixed ready for use. The

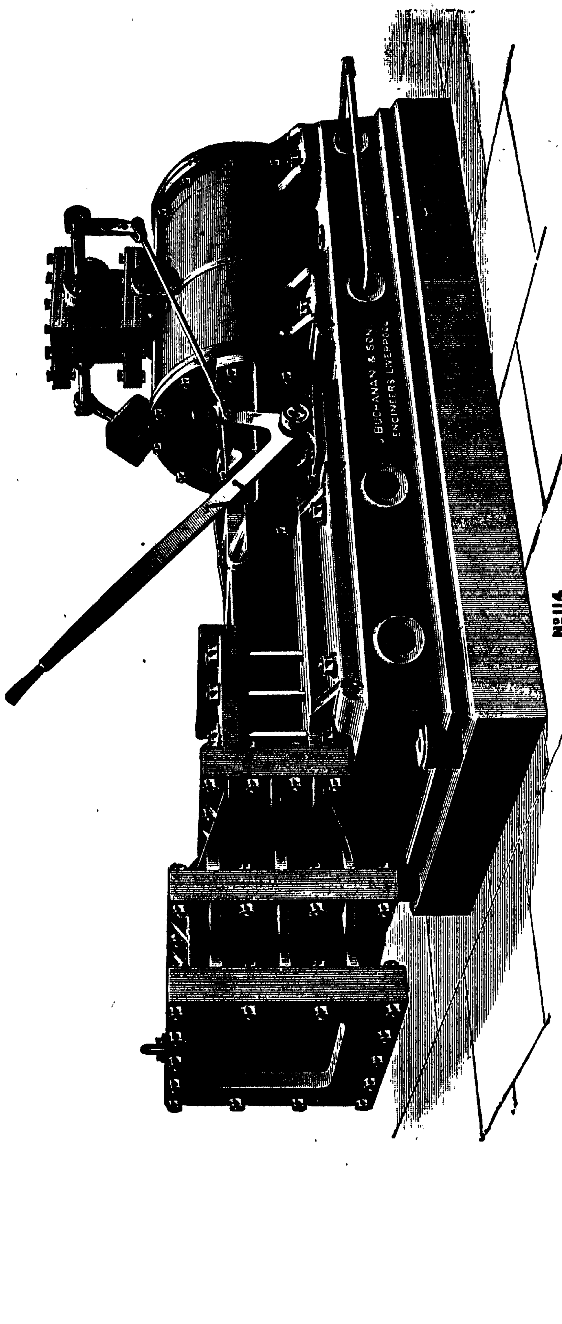


FIG. 255—"Stupid" for making hollow blocks.

framework and cores must be very strong as the pressure of the clay on them is very great, and unless they are sufficiently well built, they will be bent by the clay paste in its passage.

Hollow and perforated bricks and blocks are burned in the usual manner, though they must usually be heated very carefully during the earlier stages up to a bright red heat, particularly when sawdust and other combustible material is mixed with the clay. Unless this material is allowed to burn out slowly with a sufficient amount of air to oxidize it, yet not enough to cause over-heating, the bricks will be discoloured and irregularly burnt.

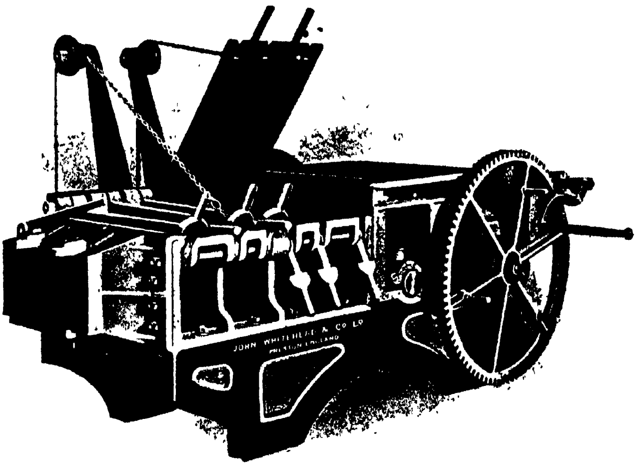


FIG. 256.—Hand-driven running-out machine.

It is a curious fact that many hollow blocks have a crushing strength quite equal to that of solid blocks of the same size. It has been suggested that this is due to the much more thorough mixing of the material which is necessary when hollow blocks are made, and to the custom of burning hollow blocks more thoroughly than ordinary bricks.

When laid in cement mortar and "reinforced," hollow blocks form one of the strongest forms of building material at present known.

Glazed hollow blocks or tubes of a shape similar to that shown in fig. 252 are much used as conduits for electrical purposes. They partake more of the nature of pottery than of bricks, and so are beyond the scope of the present work.

CHAPTER XIII

MOULDED AND ORNAMENTAL BRICKS

ORNAMENTAL slabs and bricks are generally made by hand, unless the nature of the ornamentation permits them to be made by the wire-cut process. For very simple designs, metal-lined moulds may be used, but for more ornate work plaster moulds—sometimes in several pieces—must be used.

A brick of the required design is first carved in plastic clay a little larger than the size of the finished brick, so as to allow for contraction in drying and firing. This "model" must be very carefully and accurately made, as any defects in it will be reproduced in future bricks. As soon as the modeller has completed his work the mould-maker places it on a board and brushes it over with a solution of soft soap in water to which a little tallow has been added, the boards being very similarly treated. He next places several boards or a piece of linoleum around the model, carefully stopping up any holes with clay paste, so that a case is formed into which the liquid plaster can be poured without any leaking away. Plenty of clay paste should be used, as a leak is very troublesome, and, for added strength, the boards or frame used should be fastened together with nails or cord.

The inside of the case is brushed over with soap solution, and the mould-maker next mixes a quantity of "superfine" plaster of Paris with water in a bucket, so as to obtain a thick slip, and stirs this well with his hands, so as to mix it thoroughly. The amount of plaster needed must be judged by experience, the beginner will not go far wrong if he half fills a bucket with water and sprinkles the plaster rapidly into it until it no longer sinks into the water, but the proper proportions can only be ascertained by trial.

The plaster-slurry must be worked with the hands until it is free from lumps and is of a smooth, creamy consistency; it is then poured slowly and steadily into the case by an assistant, whilst the mould-maker uses one or both hands to stir it slightly,

and prevent air-bubbles forming between the model and the plaster. Sufficient plaster must be poured in to cover the model to the depth of about 2 in. or 3 in. The whole is now left until the plaster has set, after which the casing is removed, the plaster mould turned upside-down and the clay cut out with a knife or torn out with the fingers, great care being taken not to damage the mould. Sometimes the model will drop out whilst the mould is being turned, but if it does not do so it must be cut out. The mould is then set aside to dry and harden before it is used. When complex designs are required, it may be necessary to make the mould in several pieces.

To reproduce bricks in such a mould, it is laid on a bench and a piece of clay paste thrown into it with considerable force and pressed well into the crevices of the mould. More paste is thrown in and pressed in until the mould is full. Any excess of clay is removed by drawing a strike or a stretched wire across the face of the mould, the clay being then smoothed (if necessary) with a large, flexible-bladed knife. The mould with its contents is then set aside until the clay is sufficiently dry for it to be turned out of the mould. If the mould is properly made and filled, the bricks should not require any further finishing, but it will often be found necessary to "touch them up" slightly with a modelling tool before setting them aside to dry completely. When very large blocks are made in this way, the drying requires much time and care, but ordinary sized bricks offer but little difficulty in this connexion. The burning may be carried out in any ordinary kiln, but as the colour of ornamental bricks is usually important, they should be so placed in the kiln as not to be discoloured by dust or flame.

Glazed blocks and slabs for fire-places are usually made in this manner from fire-clay or shale. The glaze used should, preferably, be hard-fired to prevent crazing, but as few firms have been able to create a sufficient variety of colours with hard firing, "majolica" or low temperature glazes are commonly employed. A description of this class of glazed ware to be complete would, alone, require a large volume.

CHAPTER XIV.

DRYING RAW CLAY.

It not infrequently happens during the winter months that the clay obtained is so wet that it cannot be properly treated by plant which is primarily designed for dry materials. In such a case, some means of drying the clay is necessary, and it will often be found that materials which are difficult to grind when in a plastic or sticky state will be greatly improved by being dried before treatment in the mills.

When ample time can be spared for the drying, or when it is the practice of the firm to gather dry clay and store it under cover, the arrangement shown in fig. 257 will be found satisfactory. This kind of shed, constructed of venetian shutters and chequered brickwork with a light roof, is readily and cheaply built, and will keep clay dry, or dry it slowly, at a trifling cost. The author has seen several sheds of this kind in active use, and in Germany, where the weather is warmer than it is in this country, it is all that is required in many yards. No heating arrangement is used, but every effort is made to allow access of air and to keep out the rain; consequently, on the most exposed side weather-boards are used instead of the open brickwork.

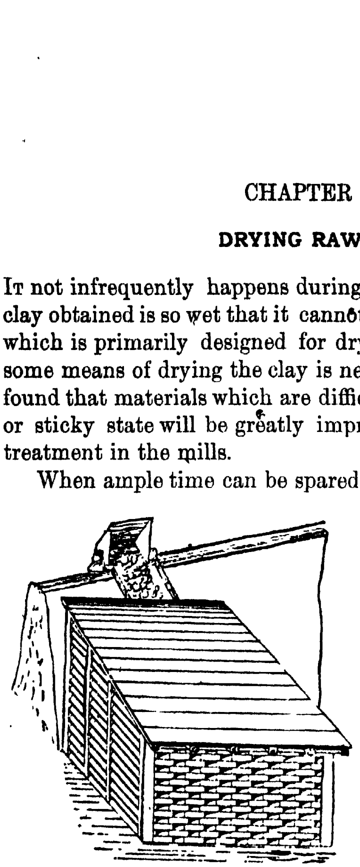


Fig. 257.—Shed for drying clay.

When a heated dryer is needed for the clay, two distinct forms are available, viz. the hot floor and the cylindrical or tubular dryer; the latter being usually the most economical.

A hot-floor dryer for raw material consists of a shed, the floor

of which is built over flues heated by fires or steam. Steam-heated floors have the advantage that they cannot spoil the material on them; but they are slow in action and fire-heated dryers are therefore more generally used.

The material is taken to the hot floor in wagons which run on a track down each side of the shed. The material to be dried is then tipped on to the floor and spread about with rakes or shovels. The portion on which the material is dried is preferably covered with iron plates which fit over the flues. Two or more flues may be used, each being about a yard in width and depth, with sufficient solid ground between to allow a wagon of clay to travel over it. The flues are heated by fires placed at one end of the shed, a transverse connected flue at the other end being connected to a chimney to produce the necessary draught. The fires should be arranged so that an ample supply of cold air can be admitted if required, in order that the temperature of the clay may not be excessive. To avoid undue risk of excessive heat, the first 3 yds. of each flue may be covered with brickwork instead of the iron plates used for the remaining portion of the flue. It is essential that the flues should be sufficiently long to utilize the heat from the fuel efficiently: 70 ft. is a suitable length for most clays.

Whilst drying, the clay should be turned over and moved about occasionally, and the roof of the shed must be well ventilated so as to carry off the steam. Clay which is almost dry should be kept away from the fire end of the flues.

Though simple in construction, floor dryers are far from economical, and tunnel dryers are, therefore, preferable. The latter are, indeed, the most suitable of all if the clay is to be dried in blocks or "balls". A typical dryer of this type, in addition to those described in a previous chapter (p. 161) is shown in fig. 258, and is equally suitable for drying bricks. The clay blocks or balls are placed on cars fitted with shelves, and travel slowly through the tunnel. The air enters the heater (*H*) and is forced into the tunnel by the fan (*V*) so that it travels in the opposite direction to the clay, as shown by the arrows.

Such a dryer is especially convenient where the clay must be dried with "pure air," on account of its colour being spoiled by fire-gases.

In tubular dryers, the clay passes down through a hollow metal cylinder (fig. 259) placed at an angle, hot gases passing along it at the same time. If the clay is very sensitive it may

be necessary to keep it out of contact with these gases by using pure air heated in a recuperator, or by surrounding the tube by another and passing the hot gases between them. To facilitate the drying the tube is usually made to revolve slowly, baffle plates

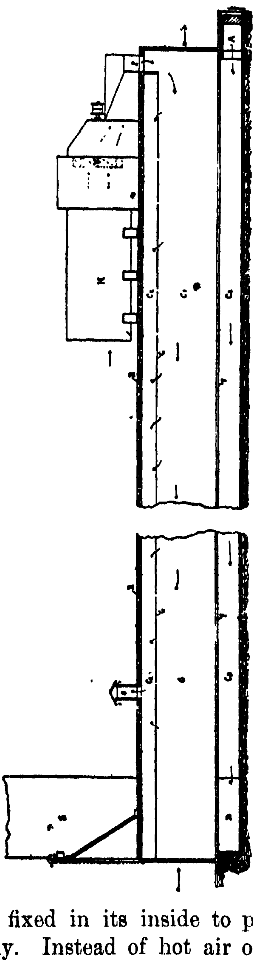


Fig. 258.—Sutcliffe drying tunnel.

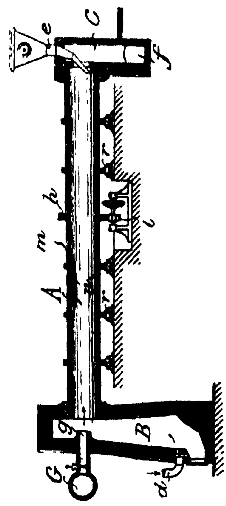


Fig. 259.—Rotary clay-dryer (gas-fired).

being fixed in its inside to prevent the clay passing out too rapidly. Instead of hot air or fire gases, steam may be used, but only for small outputs, though a level cylinder fitted with steam-pipes and a spiral worm conveyer will often be found to be far more satisfactory than a fire-heated dryer of this type.

Moeller and Pfeiffer's clay-drying drum is shown in section in fig. 260, the drum (*h*) being rotated by gearing not shown, whilst the clay enters through the hopper (*g*), and air heated by the products of combustion from the fuel on the bars (*f*) is delivered from a fan (*e*) which draws it from the farther end of the drum, and so uses part of it repeatedly, the remainder escaping through the chimney (*p*).

A good rotary dryer is somewhat costly to instal, but, if sufficiently long to utilize the heat properly, it will soon repay for itself in cases where it is required. Large lumps should, if possible, be broken up, as they dry very slowly and irregularly, and the greatest output is secured by feeding regularly and only small pieces.

Where exceedingly large quantities of clay have to be dried a

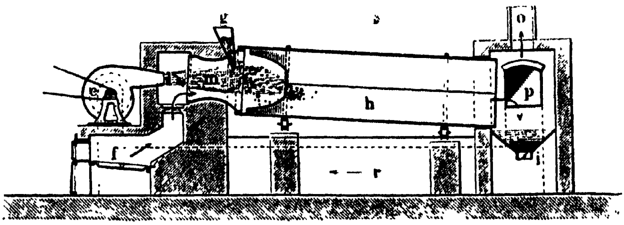


FIG. 260.—Möller & Pfeiffer's clay-dryer.

special form of shaft kiln may be used; such "tower-dryers" are, however, seldom used by British brickmakers.

If the material contains less than 5 per cent of moisture on leaving the dryer it will be satisfactory; there is no need to dry it completely and there is a considerable risk involved in doing so. Care is necessary to prevent any part of the clay from becoming over-heated and so losing its plasticity.

It is generally understood that 100° C. is the maximum temperature permissible in drying clay, but Bleininger has found that highly plastic clays kept at 200° C. for some time become less sticky and are far easier to work. This super-drying is of great importance with surface clays and with materials similar to "London clay".

CHAPTER XV.

SOURCES OF DIFFICULTY AND LOSS.

THE difficulties and losses met with in the manufacture of bricks are numerous and varied, yet they may be traced to four main sources: (*a*) improper materials or site; (*b*) unsuitable methods of manufacture; (*c*) lack of capital, and (*d*) defective accounting. Any one of these may be sufficient to wreck an otherwise satisfactory business, and it is, therefore, useless to suggest that one is more important than the rest.

Improper materials or site. Under this term may be included all those errors of judgment which have resulted in the establishment of brickworks too far removed from good markets, or on land which can, at best, produce only an inferior quality of bricks.

Brick manufacturers are particularly prone to erect works without any regard to the position of the railway or of the market to be supplied, and the author is acquainted with a number of instances where a small knowledge of geology would have saved the firms concerned many hundreds of pounds per annum in cartage alone. Not having this knowledge, works have been erected at one part of a clay deposit at some distance from the road or railway, whereas the same deposit extends close to the railway line. Instances of works constructed on unsuitable sites are far more common than is usually supposed, and the average brickmaker would be wise to obtain independent and expert advice before completing the purchase of land or works, particularly when new works are to be erected.

There are many clay beds which are notoriously difficult to work, and from which the inexperienced brickmaker should be warned, did he but accept impartial advice before it is too late.

Two of the best known deposits which are responsible for many "failures" are the "London clay" and the various "drifts" or "boulder clays" which occur in Lancashire and several other counties.

The first of these is treacherous because it is strong and sticky

without being truly plastic, and is of such an inferior nature that it can never be used alone for good work. The second material is so variable in its composition as to require constant care on the part of some capable and responsible person, or material of a nature quite unsuitable for brickmaking, and yet not easily distinguished from clay, may be sent to the mills and cause a serious amount of damage. Boulder-clay is used successfully by many careful manufacturers for the production of common bricks, but they are ever on the alert to prevent unsuitable material being dug and used. Were a bed of boulder-clay to be worked by steam navvies (as the Peterborough clay), the irregular composition of the material would bring about the financial ruin of the manufacturer unless the deposit was unusually "clean".

Other clays, in other districts, must also be carefully studied if satisfactory results are to be obtained, and those sites carefully avoided where the clay is of an unsuitable character.

The value of a clay bed can only be ascertained as the result of extensive tests, involving the use of at least several hundredweights of material. Opinions based on the examination of a few ounces of clay may be accurate, or otherwise, according as the sample truly represents the whole bed, or is only equivalent to the worse or better portions of it.

Imperfect tests often lead to serious trouble for all concerned, and the opinion of a foreman or of a public analyst should never be accepted as sufficient, unless confirmed by tests on a relatively large scale. Even the opinion expressed by a specialist in clay-working may be erroneous if he is not placed in full possession of the facts, though he is, by virtue of his special knowledge, less liable to serious error than are others who give an opinion based on a more limited experience.

Unsuitable methods of working are an exceedingly common source of difficulty and loss. Many brick manufacturers are led to put down plant without due consideration of the characteristics of their clay, and later are tempted to replace it by other plant equally unsuitable. In one case known to the author, a firm purchased no less than four different sets of machinery, each by different makers, and were contemplating experiments with a fifth when they were persuaded to take independent advice and to utilize various pieces of machinery in their possession. The difficulty in this instance lay in the peculiar nature of the material; but instances of grinding-mills or brick-making-machines being replaced by those of other makers, for

reasons which are quite insufficient and only show the ignorance of those concerned, are by no means uncommon.

Erroneous methods of working can only be put right by those having sufficient knowledge of the clay used, and are so situated as to be able to give impartial advice. A machinery maker is obviously not in this position, and it is only in the employment of an expert who, it is known, never accepts commissions or other "remuneration" from the sellers of particular machines or kilns, that a reliable means of overcoming the difficulty can be obtained.

Unfortunately, the average brickmaker is fond of asking advice of all and sundry without placing the information so received at its proper value. He is, therefore, often in the unpleasant position of having paid an excessive price for a simple piece of plant (such as a riddle) or of having purchased a machine which he learns, later, is quite unsuited to his needs. Either position is regrettable, but can only be avoided by using the means suggested, and, to a certain extent, by independent study of the subject.

Lack of capital is stated to be the cause of three-quarters of the failures of various brickmaking firms. Whilst it is not impossible that some of these business failures are really traceable to other sources, the fact remains that it is generally risky to start without sufficient capital to pay for all the plant and to keep the place going for at least six months, and preferably for a year, without any bricks being sold during that time. In some branches of brickmaking a larger capital is desirable. It is not always necessary that this large capital should be invested in the business, but it must be available in time of need if the firm is to be reasonably safe from premature stoppage and failure.

The fact that some years ago certain well-known brickmakers started with but a few hundred pounds and proved highly successful is not a sufficient reason for repeating the experiment at the present time, except in those places which are growing rapidly and competition is not likely to be felt for some years to come. A large number of such places exist on the outskirts of some of our smaller towns and near some of the larger ones, but great circumspection is needed before commencing work under such conditions.

Special care is necessary in the purchase of old works, as there are many of these in existence which ought never to have been erected, and a large number of others for the sale of whose goods no market exists. Such works are dear at any price, and

whilst "bargains" may occasionally be obtained, they are distinctly rare, and should only be purchased after reliable and full information has been obtained. It is never easy to ascertain the true cause of the failure of the previous occupier, but unless this can be satisfactorily explained the yard may prove anything but a source of profit. The services of a specialist having a previous knowledge of the works in question are often valuable.

In any case ample capital—either direct or in the form of reliable credit—should be available before a brickworks is started or purchased.

Defective accounting prevents many brick manufacturers from realizing their true position as soon as they should do, yet this disadvantage is comparatively easy to overcome.

As ordinarily carried out in small or medium-sized yards the manufacture of bricks requires the simplest form of book-keeping, yet many manufacturers fail to keep even this necessary minimum in a proper manner, with the result that when trade falls slack they are compelled to make special arrangements with their creditors, and to suffer discomforts which might have been avoided had they known earlier the results of their work.

It is essential that the proprietor, manager, or lessee of any brickyard should know how much his bricks are costing per 1000 from week to week. To wait until the end of the year is in many cases to postpone the consideration of the subject until it is too late.

Each week, therefore, a summary should be prepared showing the following:—

Stock—Brought forward, made, sold, rubbish, in hand.

Accounts—Owing, receivable.

Cash—Brought forward, received, paid, in hand.

This account should further be divided so as to show the main items of expenditure under the following heads: wages for manufacture, wages for repairs and other work, cost of repairs and renewals, cost of fuel, cost of oil and other supplies, other expenses (detailed).

From the foregoing should be calculated the figures per 1000 bricks as follows: (*a*) labour (including foreman) for manufacture; (*b*) fuel; (*c*) non-productive labour, and materials for manufacture, alterations and repairs; (*d*) oil and other supplies; (*e*) rent and royalty, or equivalent, and taxes, depreciation and office expenses; (*f*) exceptional expenses; (*g*) average net selling price.

This summary should be studied week by week with a viev to increasing the profit to be realized from the works, and care ful comparison should be made of the different summaries. I some instances, more detailed statements are desirable (e.g. th number of bricks set in and drawn off from each kiln), but thos mentioned are sufficient for an ordinary yard.

Certain figures will have to be averaged as they are paid fo at long intervals, but with care this need occasion no difficulty and little or no inaccuracy.

In making these comparisons from time to time it is essen tial that a broad-minded policy should be adopted, or the amoun set aside for depreciation must be increased. Thus it is foolis to reduce the expenditure on repairs and renewals below a suit able limit, as this would result in the production of an inferio brick for which a lower price would be obtained, or the wear an tear of the machinery would involve a relatively greater expens later.

When a yard is sufficiently large to justify the expense it i far better to have the whole stock and plant valued by an inde pendent valuer of established reputation in this class of work than to adopt the customary plan of writing off 5 or 10 per cen each year for depreciation.

It is also important that the sums so set aside should b kept quite distinct from the business and should be invested i other securities. Otherwise it may again be found, as has hap pened on many previous occasions, that the "reserve fund" ha no real value, as it has all been absorbed by the losses of the firm

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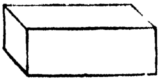
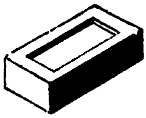
ABERDEEN: THE UNIVERSITY PRESS

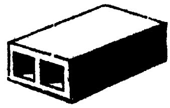
MODERN BRICKMAKING



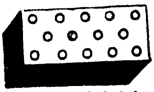
Plain brick.



Pressed brick showing "frog".

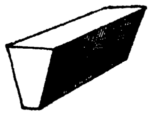


Hollow brick.

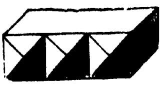


Perforated brick.

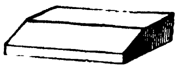
Jamb.



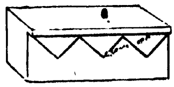
Arch brick or Wedge.



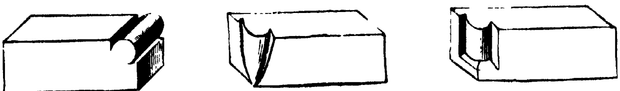
Diamond stretcher.



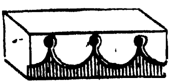
Plinth brick.



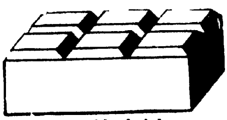
Dog-tooth stretcher.



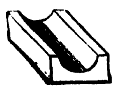
Fancy squints, or stop bricks, for corners, etc.



Half-moon stretcher.



Stable brick.



Channel brick.

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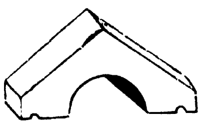
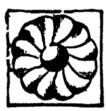
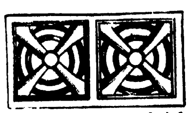


Coping brick.



String course brick.



Ventilator or air brick.

MODERN BRICKMAKING

BY

ALFRED B. SEARLE.
CONSULTING EXPERT ON CLAYS AND CLAY-PRODUCTS,
LECTURER ON BRICKMAKING UNDER THE CANTOR BEQUEST, ETC. ETC.

WITH TWO HUNDRED AND SIXTY ILLUSTRATIONS

LONDON
SCOTT, GREENWOOD & SON
"THE POTTERY GAZETTE" OFFICES
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1911

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PREFACE

THE brickmaking industry is one of the oldest known, but most of the modern methods of manufacture are of such recent growth that no single volume contains a description of the most important ones used in this country. The result is that many brickmakers are using machinery and kilns of which they have but little knowledge, and they are labouring under the disadvantage of not knowing what progress has been made.

In the present volume, the Author has endeavoured to condense the results of a wide practical experience of all the better-known processes, machines, and kilns now in use—both in this country and on the Continent—into convenient limits, and to express this information in terms which shall be readily understood by all interested in the subject. In other words, he has aimed at clearing up ideas regarding the various processes and appliances used in modern brickmaking and to remove various obscurities at present prevailing in many minds.

In this work the Author has had the hearty co-operation of all the chief firms who supply machines, kilns, and other requirements of the brickmaker, together with the assistance of numerous authors of papers, booklets, and larger treatises (both British and Foreign). Their names will usually be found attached to the illustrations, though the publication of anonymous articles in the trade journals prevents acknowledgment in some cases.

Whilst it is not possible to give a complete list, the Author hereby acknowledges, with thanks, his indebtedness to all who have been of assistance to him in the manner indicated, as well as to various members of his staff, without whose aid this volume could not so readily have been written.

From so large a mass of material, it has often been necessary to describe only one machine, or kiln, of each type, indicating, more or less fully, the points of difference between the one chosen and others equally well known. In deciding which machine, or kiln, to select for such fuller description, the Author has been guided chiefly by his personal knowledge and experience, prominence being given, whenever possible, to those designers or firms to whom the credit of introducing the process under consideration is primarily due.

The experienced brickmaker who wishes to develop a new bed of clay, or shale, as well as the capitalist unacquainted with the details of the various appliances, is often placed at a disadvantage when endeavouring to choose between the claims of various firms. After studying such details as are given in the present volume, such prospective purchasers should be able to select a given appliance or process without so serious a risk of loss as if they were ignorant of the different materials to which each process is best adapted. It is not to be supposed that the study of any book will place the reader in the position of an expert, but a careful perusal of the present work will, it is hoped, enable any intelligent person acquainted with the rudiments of the subject, to see the reasonableness or otherwise of suggestions made to him by various persons and to enable him to make use of such new methods as are mentioned in it.

To students, builders, civil engineers, and to those interested in the development of estates, as well as to brick manufacturers, the present volume will, it is anticipated, prove to contain a useful summary of the chief matters of importance in connexion with the various branches of brickmaking. Those who wish for further information on the testing, analysis and scientific control of the materials and processes involved should consult special works (by the author and others), in which these matters are more fully described.

ALFRED B. SEARLE.

THE WHITE BUILDING,
SHEFFIELD.